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(54) **GESTURE INTERFACE**

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G06F 3/0484 (2013.01)

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CPC ***G06F 3/017*** (2013.01); ***G06F 3/011*** (2013.01); ***G06F 3/012*** (2013.01); ***G06F 3/013*** (2013.01); ***G06F 3/04842*** (2013.01)

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See application file for complete search history.

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(57) **ABSTRACT**

A user interface apparatus, computer program, computer readable medium, and method for selecting a selectable object on a display screen is presented. The display screen displays one or more selectable objects. Information regarding a tracked hand position, and a tracked head or eye position of the user are obtained. Based on the tracked hand position and the tracked head or eye position, it is determined whether a said selectable object is located at a first screen position, the first screen position being a position on the display screen such that the first hand at least partly obscures the user's view of the selectable object. If it is determined as so located, then selectable object is determined as selected.

11 Claims, 21 Drawing Sheets

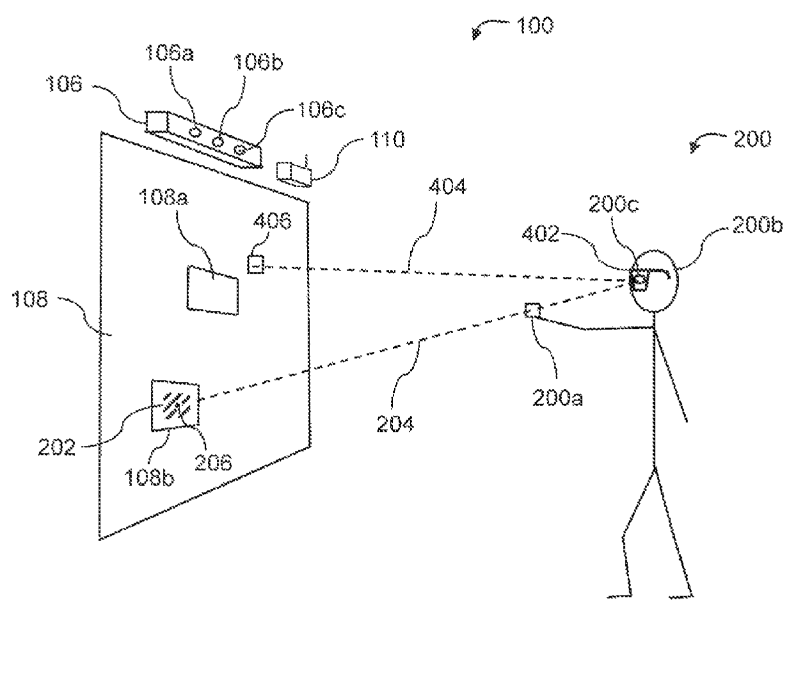

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Fig.1a

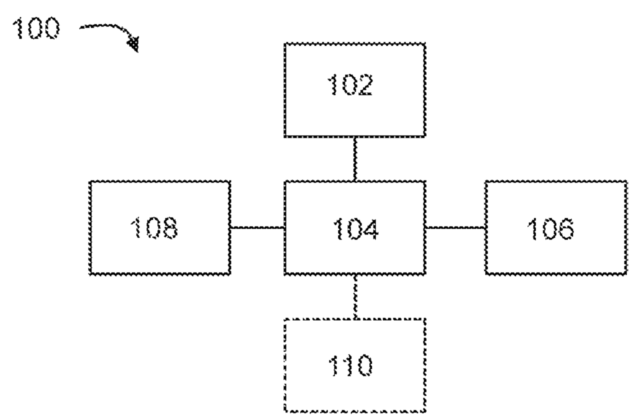


Fig.1b

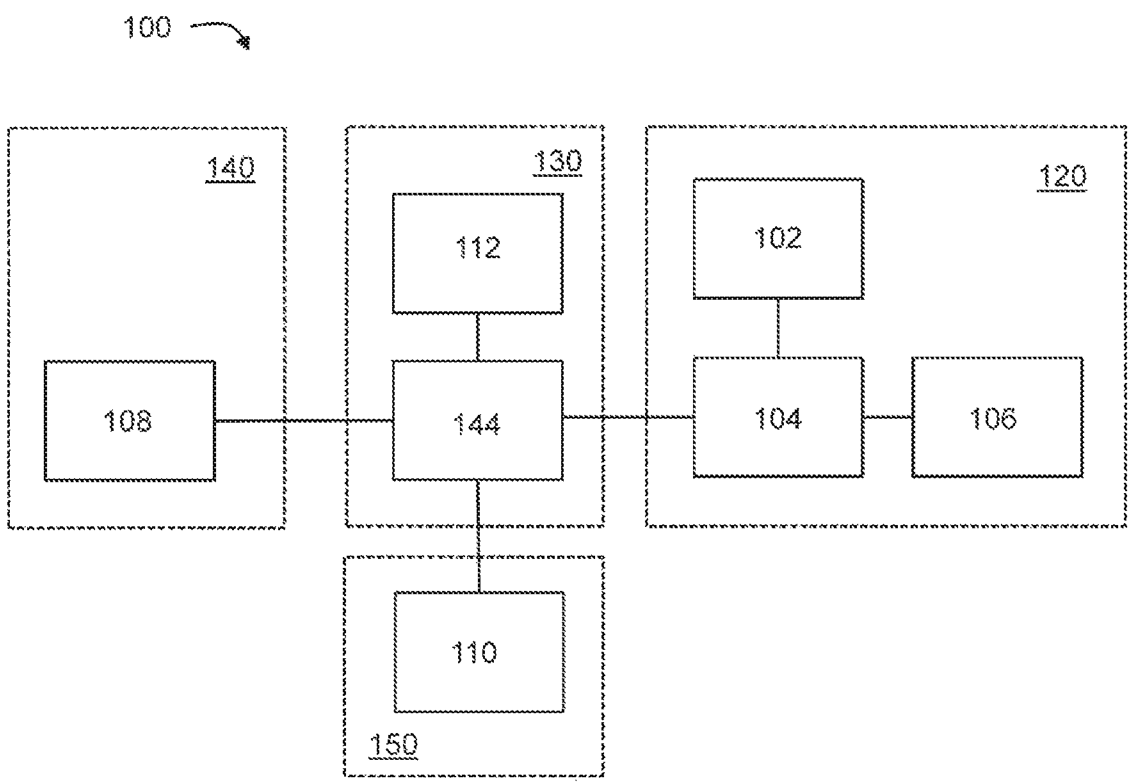


Fig.1c

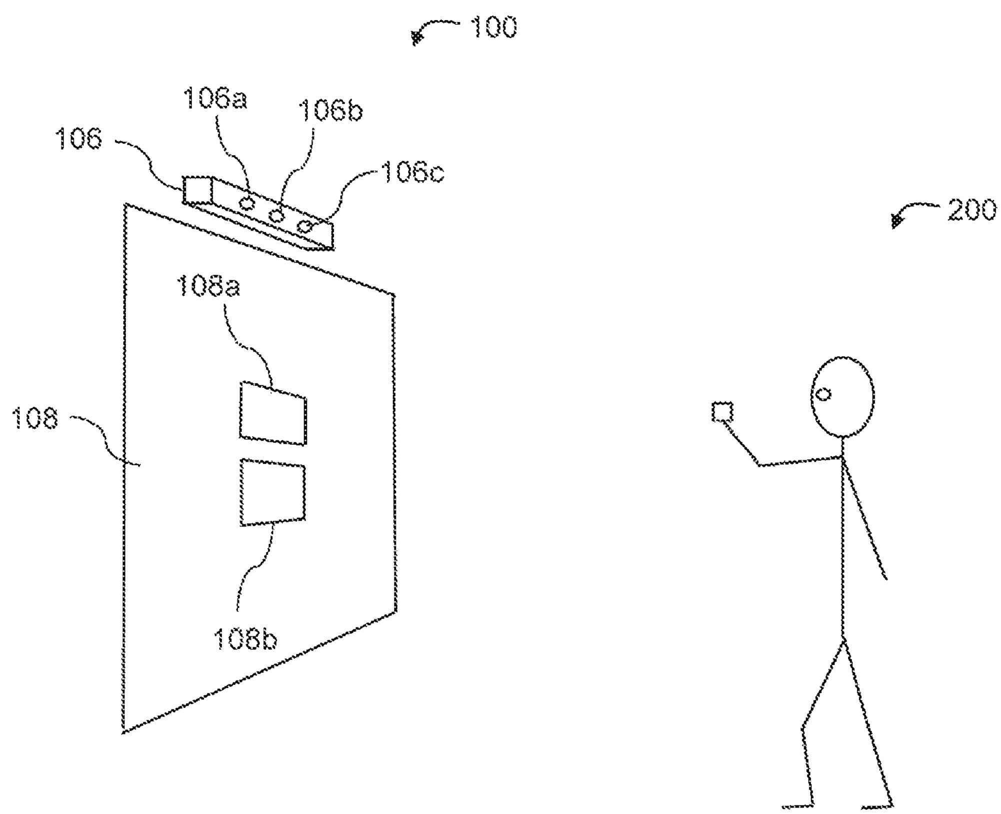


Fig.2a

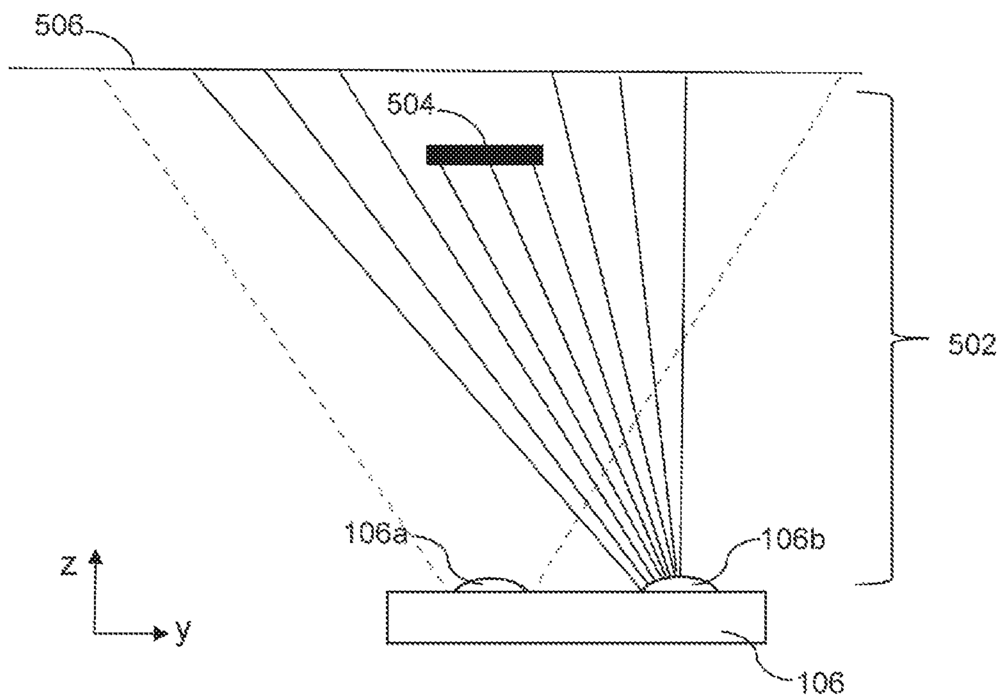


Fig.2b

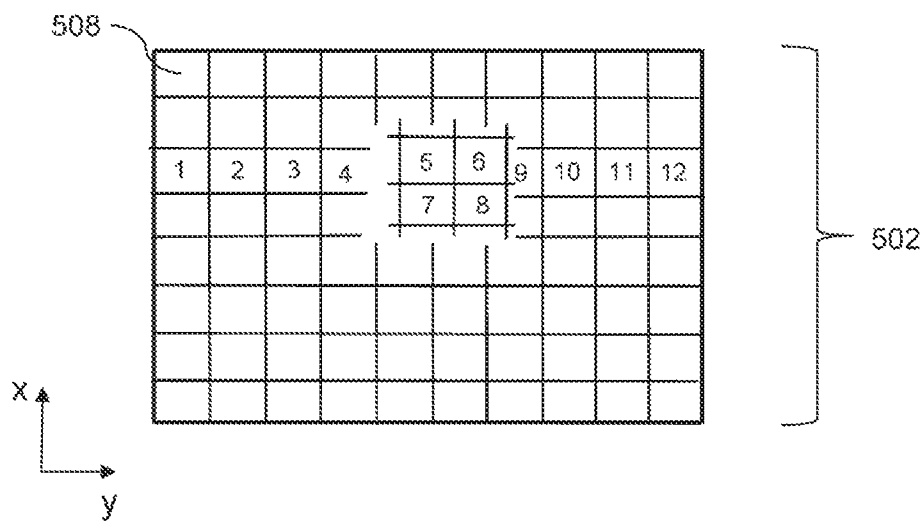


Fig.3

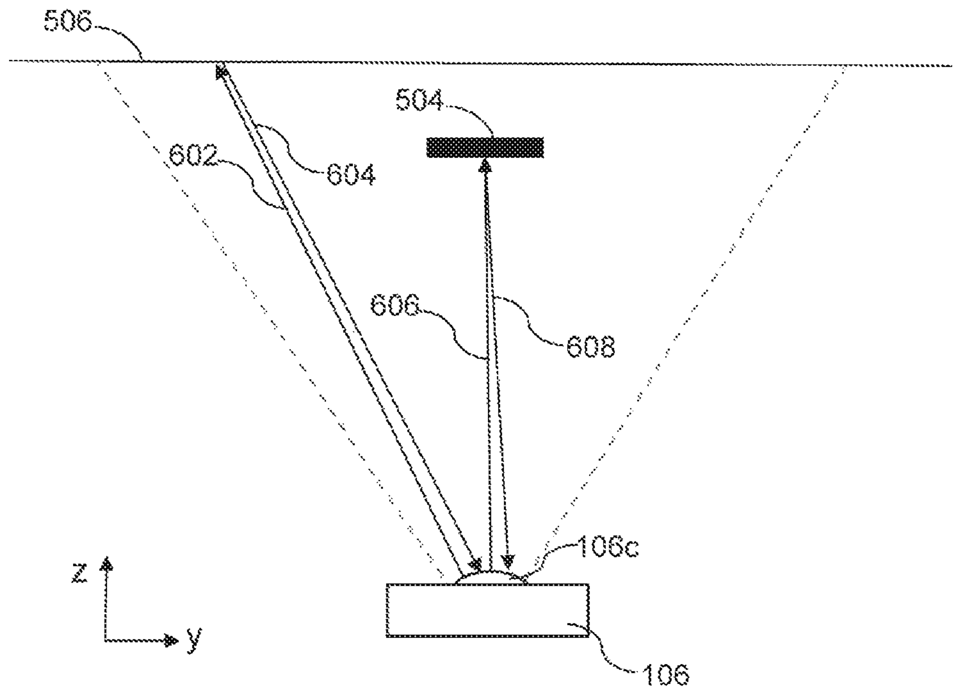


Fig.4a

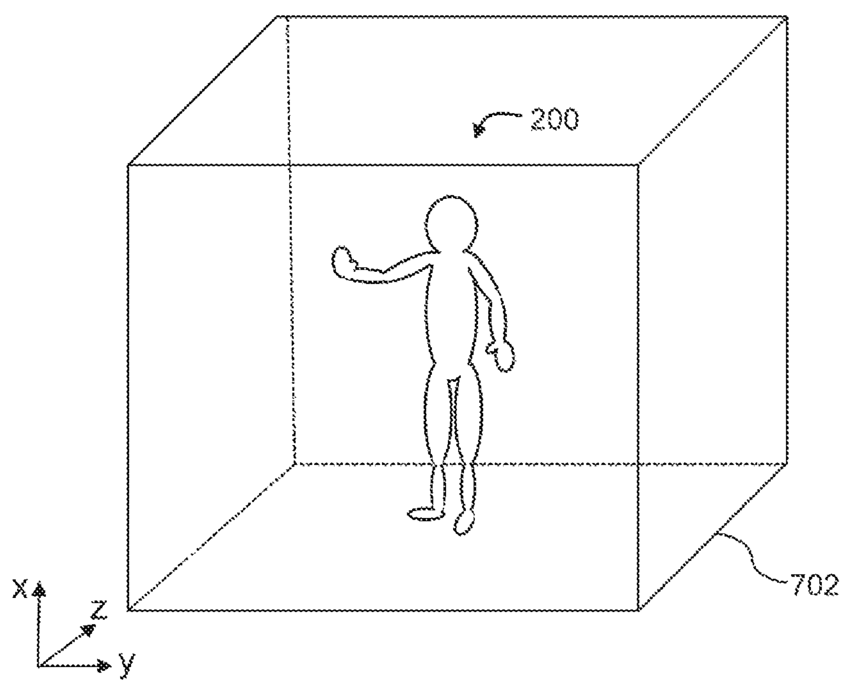


Fig.4b

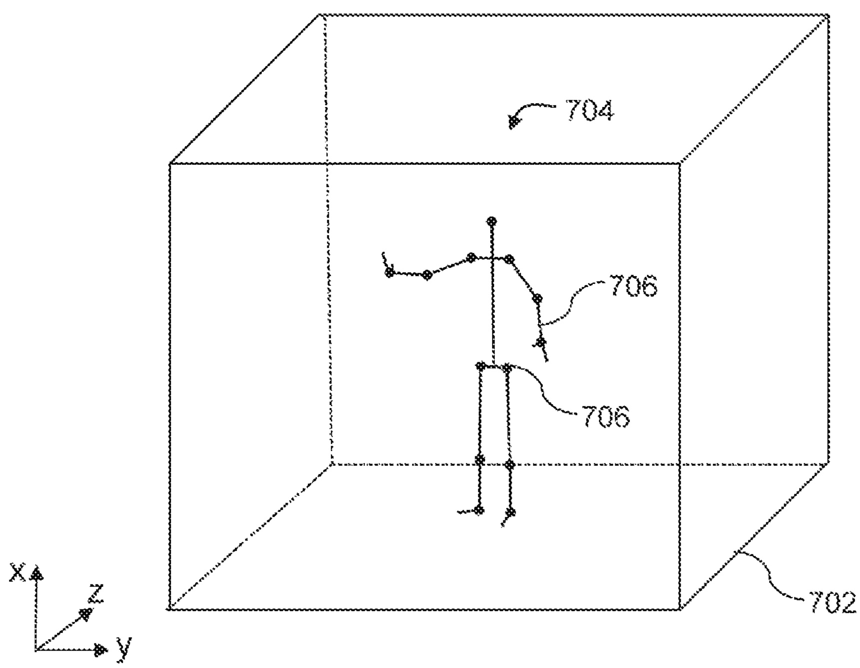


Fig.5a

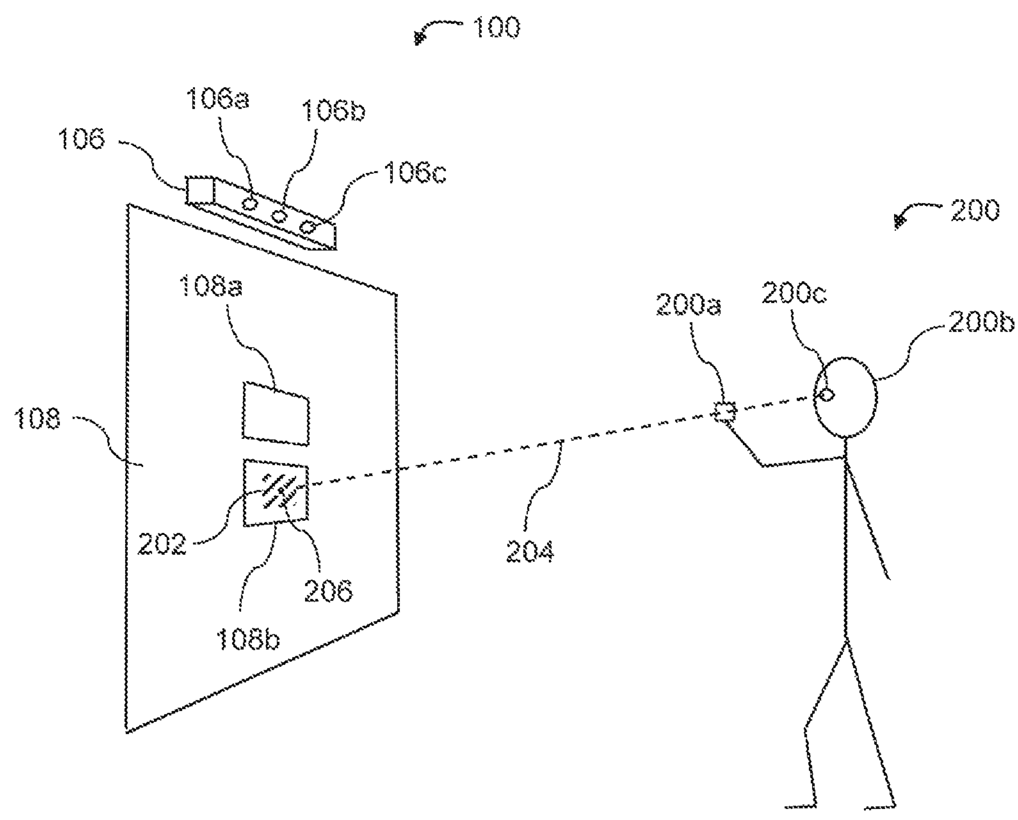

100
106
106a
106b
106c
200
108a
200a
200c
200b
108
202
204
206
108b

Fig.5b

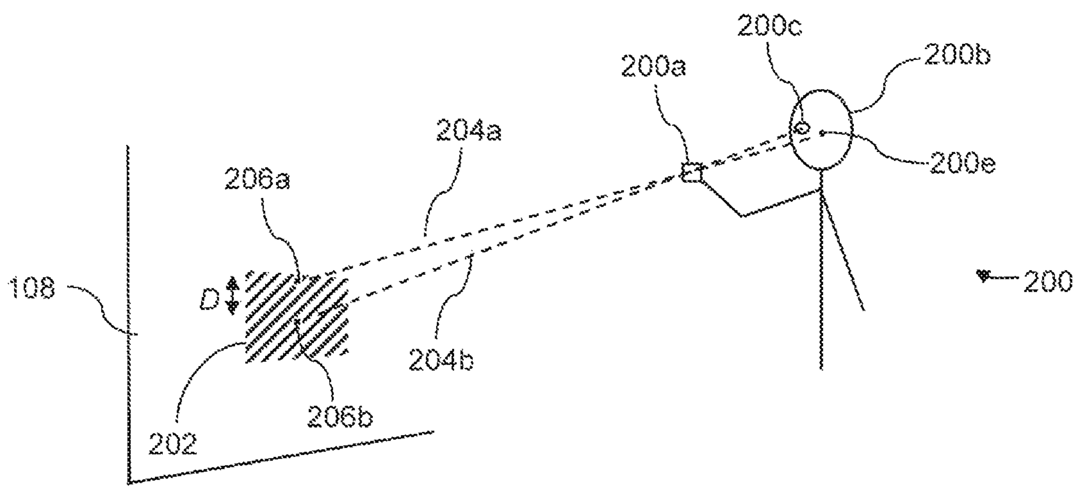


Fig.6a

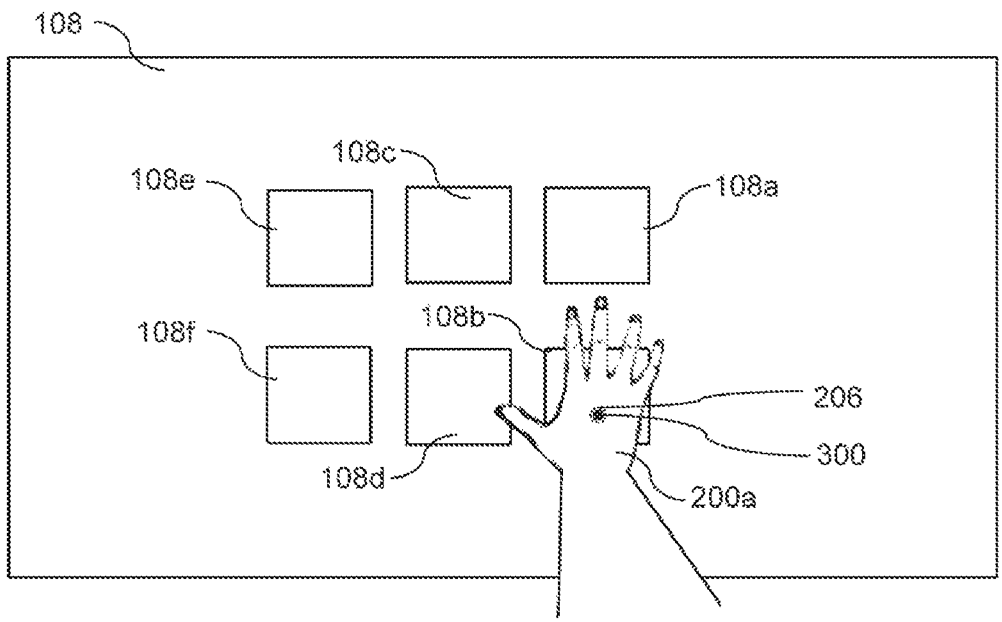


Fig.6b

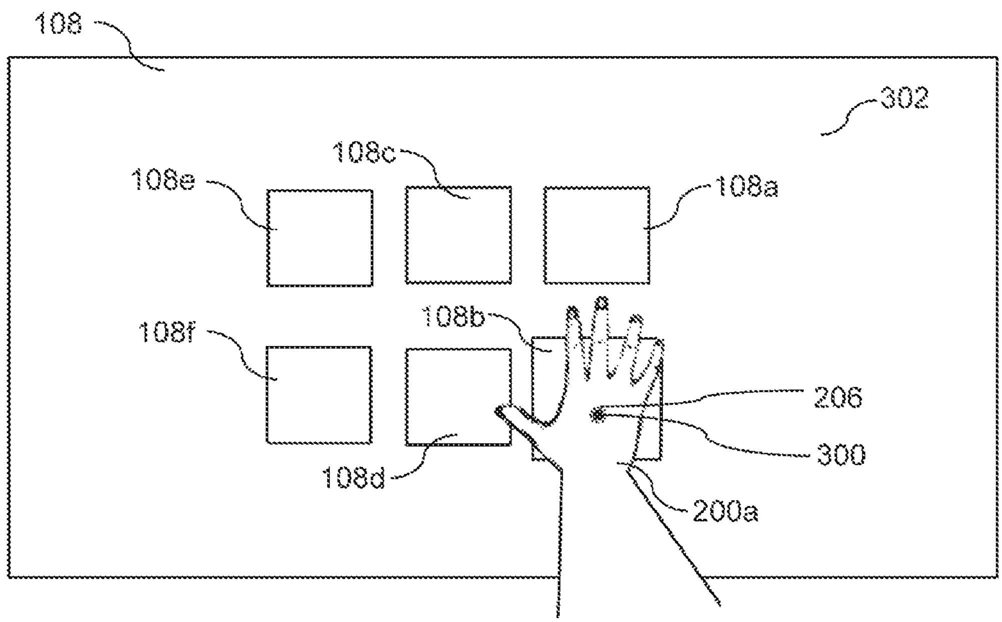


Fig.6c

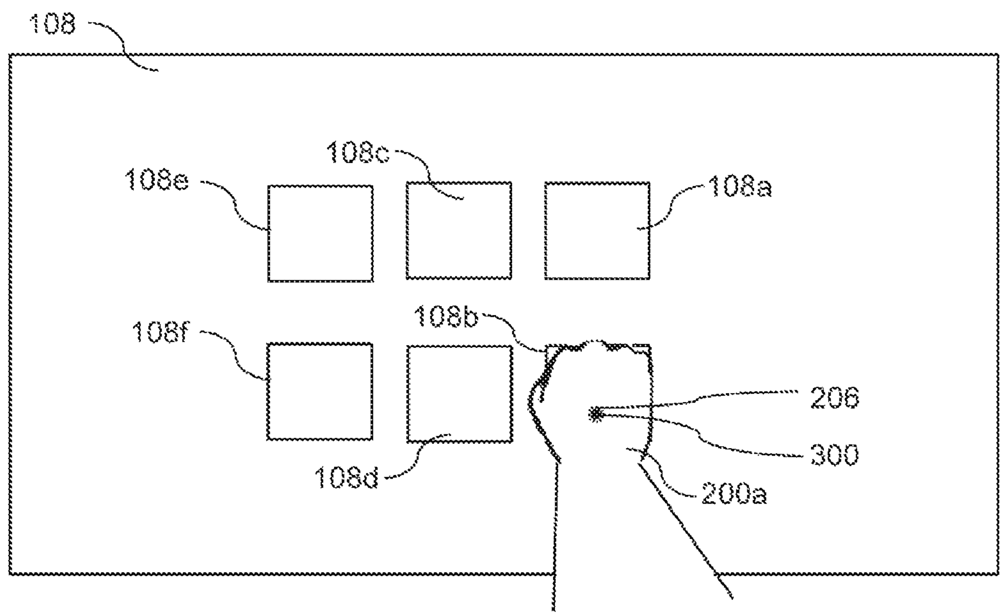


Fig.6d

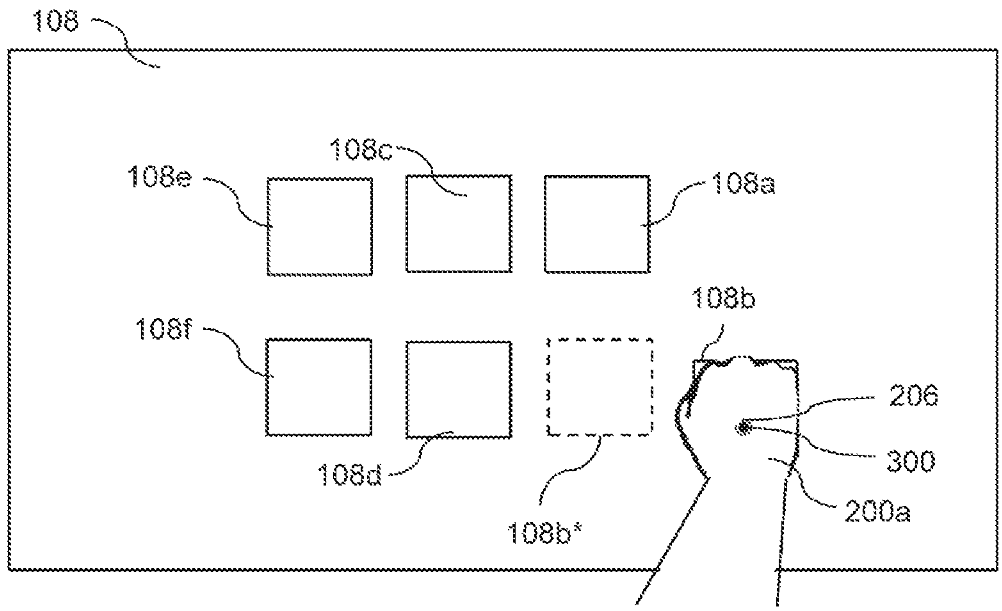


Fig.6e

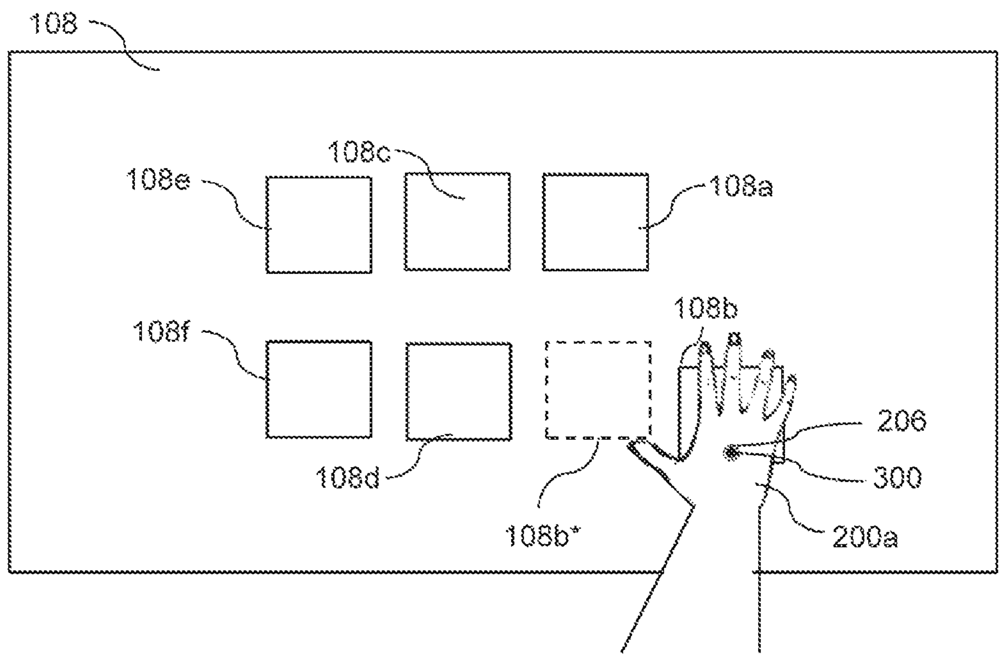


Fig.6f

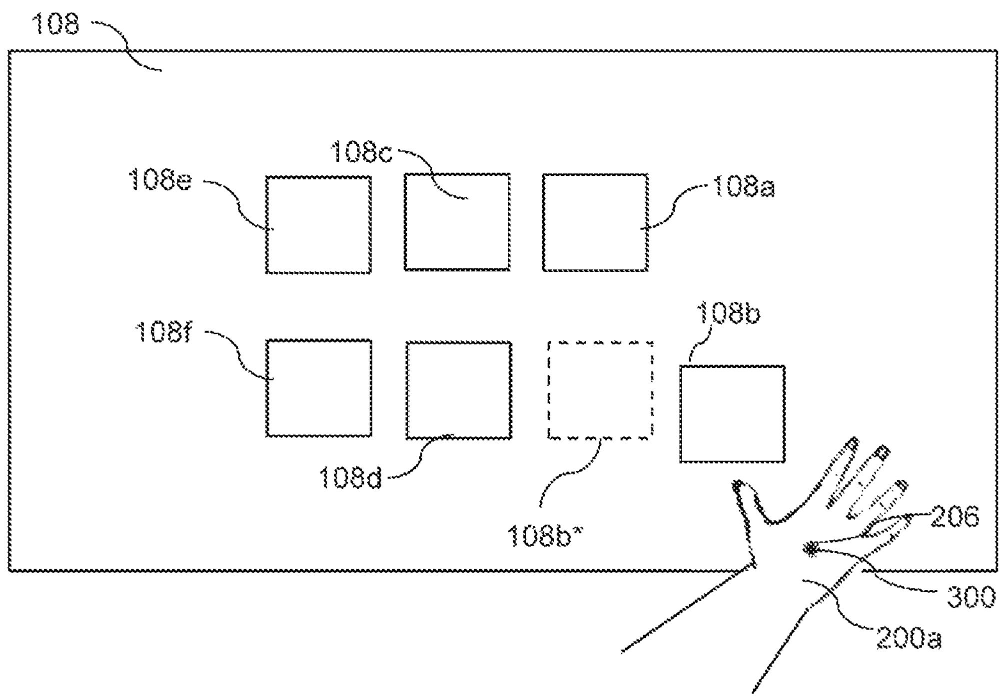


Fig.7

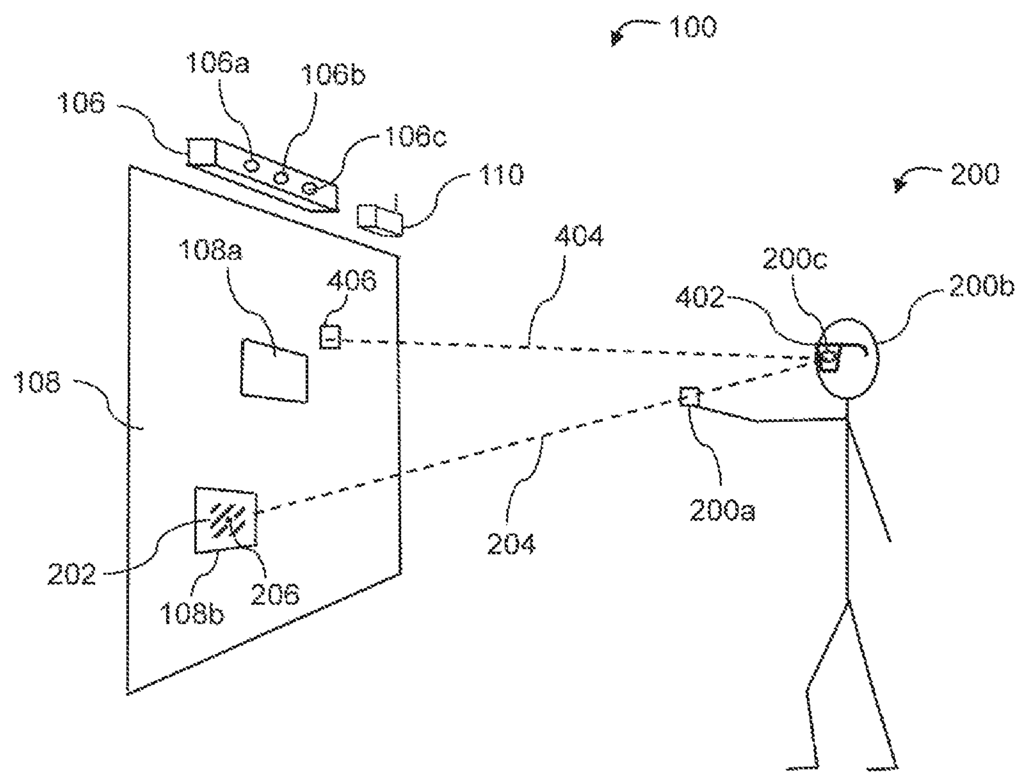

100
106a
106b
106
106c
110
200
108a
404
406
200c
402
200b
108
200a
204
202
206
108b

Fig.8

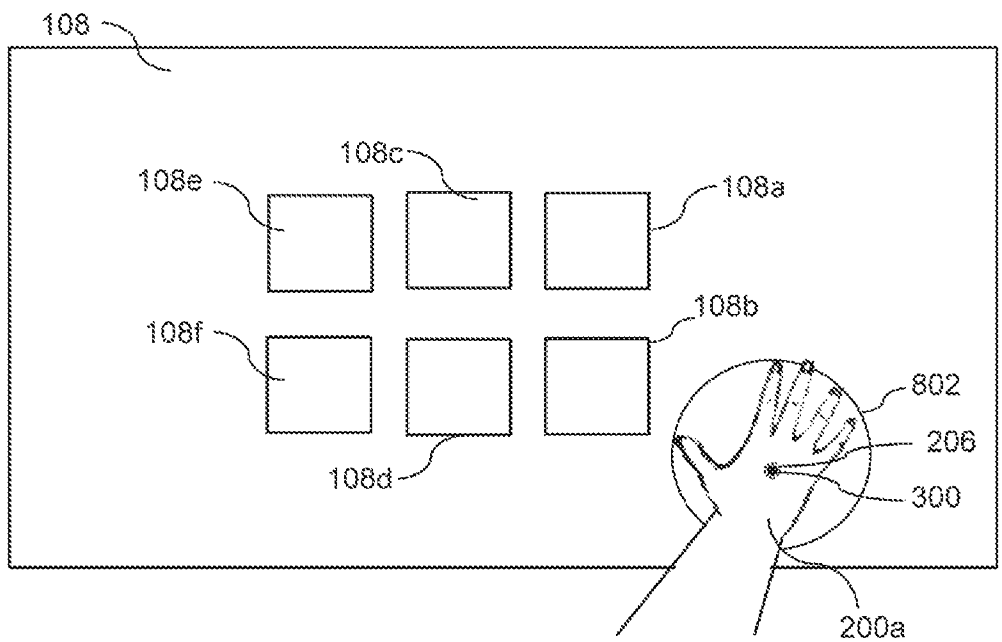


Fig.9

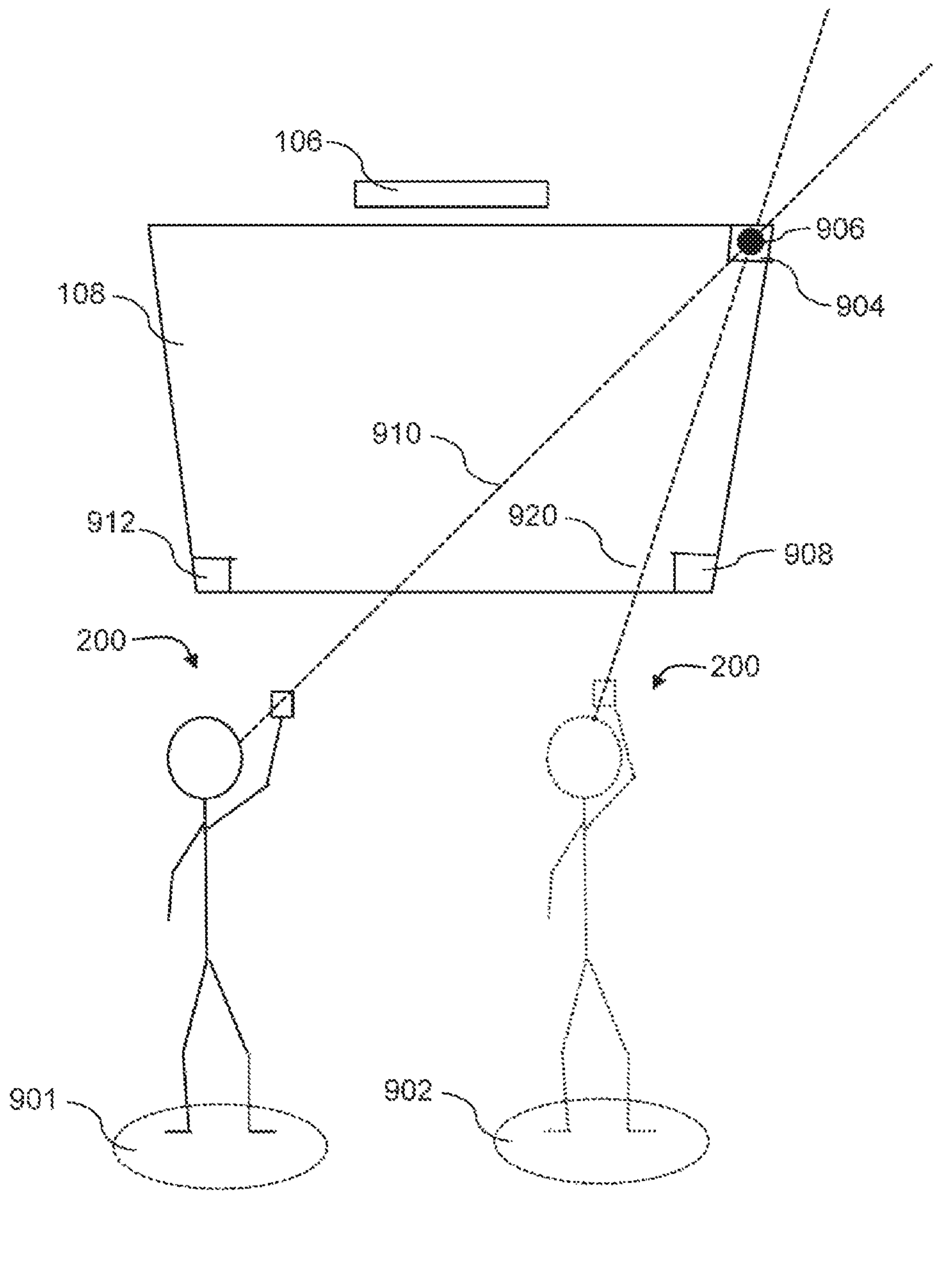


Fig.10

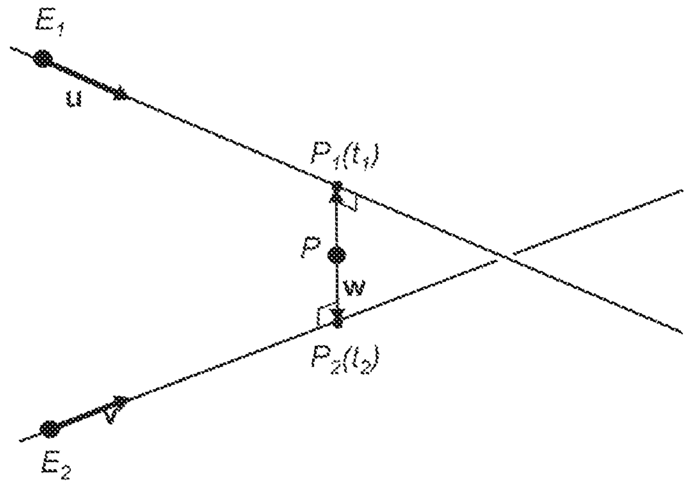
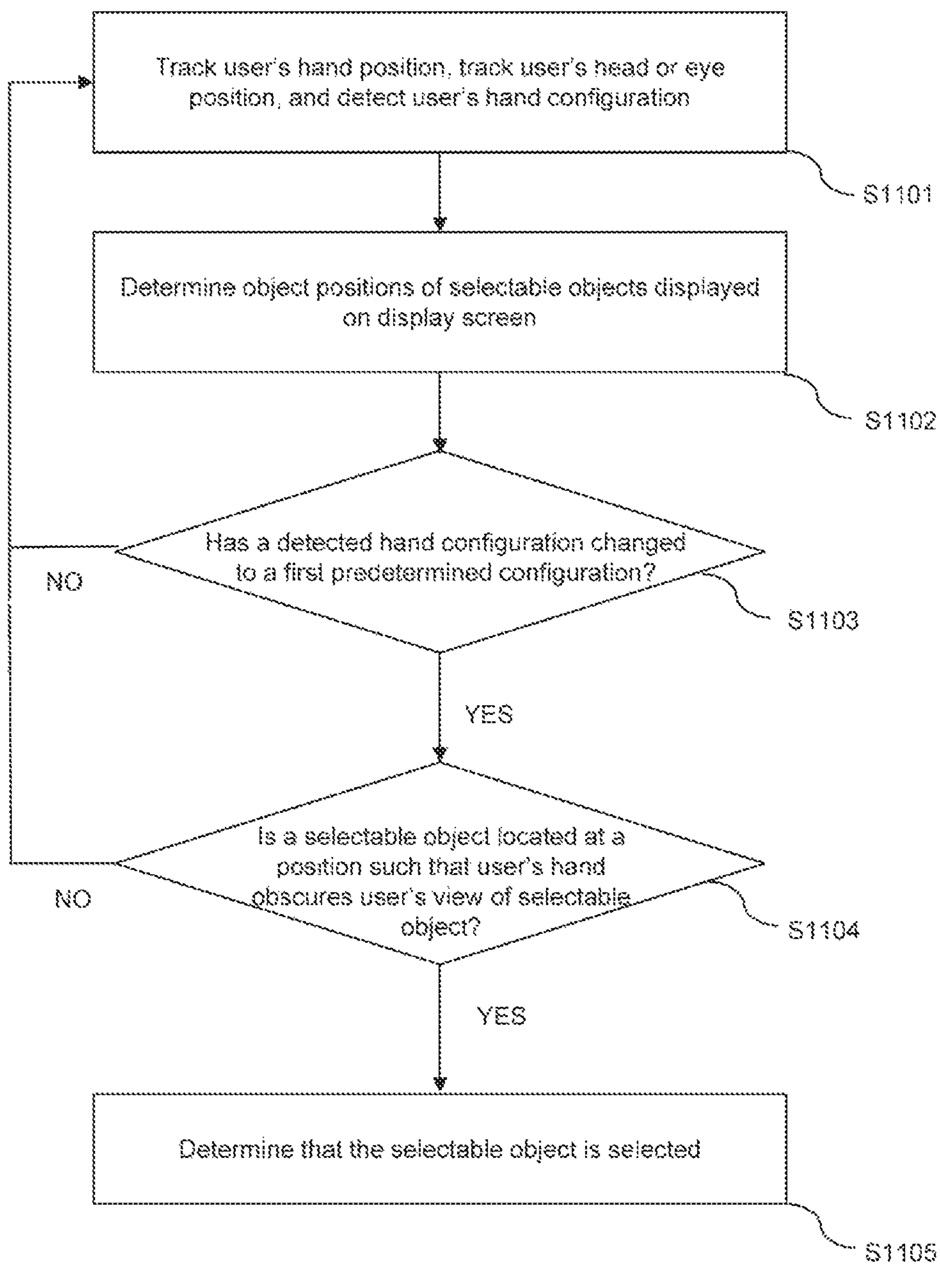


Fig.11


Track user's hand position, track user's head or eye position, and detect user's hand configuration
S1101
Determine object positions of selectable objects displayed on display screen
S1102
Has a detected hand configuration changed to a first predetermined configuration?
NO
S1103
YES
Is a selectable object located at a position such that user's hand obscures user's view of selectable object?
NO
S1104
YES
Determine that the selectable object is selected
S1105

GESTURE INTERFACE

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a National Stage of International Application No. PCT/JP2015/062316 filed Apr. 16, 2015, the contents of all of which are incorporated herein by reference in their entirety.

TECHNICAL FIELD

The present invention relates to user interfaces, and more specifically to a user interface apparatus for selecting a selectable objects displayed on a display screen.

BACKGROUND ART

Traditionally, a user may interact with a user interface of a computer or other processing system by physically manipulating a device, such as a mouse, joystick, games controller, keyboard, etc., by which the user's movements and actions may be translated into movements and actions on a display screen. In such systems, a pointer, such as a mouse pointer, is typically displayed on the display screen to allow the user to know with which part of the display he or she is interacting.

Other user interfaces, so called "Natural User Interfaces", such as the Microsoft™ Kinect™' utilise technology able to track the movements of a user's body to enable a user to interact with a user interface, for example using sensors such as cameras and the like together with image processing technology. Typically in such interfaces, a user's hand is tracked and movement of a pointer is correlated with the tracked hand movement, in analogy with the mouse technology described above. However, these interfaces are unintuitive and difficult to operate for the user. Further, because the user must first move the arm in order to find the pointer, move the pointer toward a target, and then adjust speed and amplitude of movement in order to reach precisely the target, these interfaces are inefficient and can cause fatigue in the user, especially for larger display screens.

SUMMARY OF INVENTION

According to a first aspect of the present invention, there is provided a method for use in a user interface apparatus for selecting a selectable object on a display screen, the display screen being arranged to display one or more selectable objects, the method comprising: obtaining first information regarding a first tracked position, the first tracked position being a position of a first hand of a user; obtaining second information regarding a second tracked position, the second tracked position being a position of the head or an eye of the user; determining one or more object positions of the one or more selectable objects on the display screen; determining, based on the first information, the second information and the determined one or more object positions, whether a said selectable object is located at a first screen position, the first screen position being a position on the display screen such that the first hand at least partly obscures the user's view of the selectable object; and in the case of a determination that the selectable object is located at the first screen position, determining that the selectable object is selected.

Further features and advantages of the invention will become apparent from the following description of preferred embodiments of the invention, given by way of example only, which is made with reference to the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIGS. **1**a-**1**b show schematic diagrams of the components of a user interface apparatus according to exemplary embodiments;

FIG. **1**c shows an illustration of an exemplary user interface apparatus in use by a user according to an embodiment;

FIG. **2**a is a schematic diagram of an exemplary method of sensing depth information;

FIG. **2**b is a schematic diagram of information obtained in an exemplary method of sensing depth information;

FIG. **3** is a schematic diagram of an exemplary method of sensing depth information;

FIG. **4**a is an illustration of a rendering of a user in virtual three dimensional space;

FIG. **4**b is an illustration of a generated virtual representation of a user in virtual three dimensional space;

FIG. **5**a is an illustration of a user interface apparatus in use by a user according to an embodiment;

FIG. **5**b is an illustration of definitions of a head-hand line and an eye-hand line according to exemplary embodiments;

FIGS. **6**a-**6**f are illustrations of a display screen from the perspective of the user, according to exemplary embodiments;

FIG. **7** is an illustration of a user interface apparatus in use by a user according to an embodiment;

FIG. **8** is an illustrations of a display screen from the perspective of the user, according to an exemplary embodiment;

FIG. **9** is an illustration of a portion of a calibration process according to an embodiment;

FIG. **10** is a schematic diagram of a near intersection of two straight lines; and

FIG. **11** is a flow diagram showing a method performed by a user interface apparatus according to an embodiment.

DESCRIPTION OF EMBODIMENTS

FIG. **1**a is a schematic diagram of the components of a user interface apparatus **100** according to some exemplary embodiments. The user interface apparatus **100** comprises sensor component **102** for tracking the position of a user, processor **104**, memory **106**, and display screen **108** for displaying information to a user.

The processor **104**, using software stored in the memory **106**, processes information input to the processor **104**, and generates information that is output from the processor **104**. For example, information relating to the position of a user of the user interface apparatus **100** obtained by the sensor component **102** may be sent to the processor **104** for processing, and information for use in displaying visual information to the user on the display screen **106** may be sent to the display screen **106** from the processor **104**.

The display screen **108** may comprise any means for displaying information to a user of the user interface apparatus **100**, and may display a user interface, for example a graphical user interface, to the user. The display screen **108** may be a projector screen **108**, and the visual information may be projected by a projector (not shown) onto the projector screen **108** such that the user can see the visual information. The projector screen **108** may be any suitable surface for enabling a user to see a graphical user interface or the like projected thereon.

The sensor component **102** may comprise any number of sensors for sensing attributes of the local environment in which a particular sensor is located, and more specifically for sensing attributes of a user of the user interface equipment. For example, the sensor component may comprise a camera for acquiring images of a user, or a portion of a user. The camera may be, for example, a "Red-Green-Blue" (RGB) "Charge Coupled Device" (CCD) camera for acquiring colour images of the user and the user's environment. The camera may acquire a plurality of such images as a function of time so as to acquire a moving image of the user and the user's environment, and hence acquire information relating to the movement of a user or a portion of the user. As will be described in more detail below, the sensor component **102** may comprise sensors for acquiring depth information as a function of time so as to enable three dimensional tracking of the position of the user or portions of the user in three dimensional space. Depth sensing may be achieved for example using "time-of-flight" sensors or "structured light" sensors to determine the distance of an object from the sensor. The sensor component **102** feeds sensing information relating to, for example the attributes and or positions of the user, to the processor **104** for processing. The user interface apparatus **100** need not necessarily comprise sensor component **102**, which may instead be remote from user interface apparatus **100**. In such a case, the sensor component **102** may be communicatively connected to user interface apparatus **100** by a communications interface (not shown) of the user interface apparatus **100**, for example via fixed or wireless connection. This connection may carry, for example, information regarding the tracked positions of portions of the user from sensor component **102** to user interface apparatus **100**.

In one embodiment, the user interface apparatus **100** comprises a gaze-sensor component **110** for tracking the direction in which a user of the user in interface apparatus is looking. For example, the gaze-sensor component may track the position on the display screen **108** at which the user's eyes are directed. The gaze-sensor component **110** may comprise any number of sensors suitable for tracking a gaze direction of a user. The gaze-sensor component may comprise sensors attached to the user **200**, for example a camera for acquiring images of a user's eye, and, for example, a magnetometer for sensing the direction in which a user's head is facing with respect to a fixed magnetic field, or an image processing system utilising facial recognition software, to determine the direction in which a user's head is facing relative to display screen **108**. However, any other sensor or combination of sensors suitable for tracking the gaze direction of a user may be used. For example, the gaze sensor component **110** may also comprise remote gaze sensors which track the gaze direction of a user by projecting near infrared patterns onto the user and imaging the projected patterns reflected from the user's eyes in order to determine the position of the eyes, and hence the gaze direction of the eye, relative to the micro projector. In any case, in this embodiment, the gaze sensor-component **110** provides the processor **104** with information relating to the gaze-direction of the user.

FIG. **1***b* shows a schematic diagram of components of a user interface apparatus **100** according to some exemplary embodiments. In these embodiments, the user interface apparatus comprises a sensing module **120**, a gaze sensing module **150**, a processing module **130**, and a display module **140**. The processing module receives information relating to, for example, the position of the user or portion of the user acquired by the sensing module **120**, and/or information relating to the user's gaze direction acquired by the gaze-sensing module **150**, and processes, utilising the memory **112**, the information using processor **114**. The sensing module **120** comprises a sensor component **102**, a processor **104** and a memory **106**. The processor **104** is for, for example processing information generated by the sensor component **102** and providing information to the processing module **130**, for example relating to the position or attribute of the user or a portion of the user in a format recognisable by the processing module **130**. The gaze sensing module **150** may comprise a gaze sensor component **110** as described above. The display module **140** comprises display screen **108**. The processing module **130** provides information to the display module **140** relating to, for example, information for the display module **140** to display to the user using display screen **108**. The processing module **130** need not necessarily be co-located with any of the other modules. For example, the processing module **130** may be located on a server located, for example within the internet. The processing module **130** may obtain information regarding positions of portions of the user, for example from sensing module **120**, and/or gaze sensing module **120**, over the internet. The processing module **130** may also provide information to the display module **140** for displaying to the user over the internet. As such, the user interface apparatus **100** may be embodied solely on processing module **130**, which, as described above, may be located on a server in the internet.

In some embodiments, the user interface apparatus **100** does not comprise a gaze-sensing module **150** or gaze-sensing component **110**.

In a specific example, the sensing module **120** may be a Microsoft™ Kinect™, the processing module **130** may be a personal computer or a Microsoft™ Xbox™, and the display module may comprise a projector projecting onto a projector screen.

FIG. **1***c* is an illustration of an exemplary embodiment of user interface apparatus **100** in use by a user **200**. Shown in FIG. **1***c* is sensor component **106**, comprising sensors **106***a*, **106***b* and **106***c* directed towards the user **200**. Also shown is display screen **108**, towards which the user **200** is facing. As described in more detail below, by determining the position and/or configuration of portions of the user **200**, the user interface apparatus **100** may enable the user **200** to interact with selectable objects **108***a* and/or **108***b* displayed on the display screen simply by the movement of the user's body.

A method by which depth information, and hence three dimensional position information of a user, can be acquired and determined by user interface apparatus **100** will now be describe with reference to FIGS. **2***a* and **2***b*.

FIG. **2***a* is a schematic diagram of a plan view (i.e. the z-y plane as indicated in FIG. **2***a*) of an exemplary sensor component **106** of a user interface apparatus **100**, sensing the three dimensional position of the object **504** against background **506**. The object **504** may be a user **200**, or a portion of a user **200**. The sensor component **106** comprises two sensors **106***a* and **106***b*, which are separated from each other in a plane perpendicular to the principle axis of each sensor. Sensor **106***b* is a light emitting device that produces a structured pattern of light **502** which is cast onto the object **504** and the background **502**. Sensor **106***a* is a sensor for acquiring images of the structured light pattern **502** as it is cast onto the object **504** and the background **506**. The light **502** may be, for example, infra-red radiation, and the sensor **106***a* may be an infrared sensor, which may include a band pass filter centred on the frequency of the structured light **502** so as to increase capture efficiency of the structured light pattern **502** as it is cast onto object **504** and background **506**.

The structured light **502** may be, for example, in the form of a two dimensional grid of light **502**. Each element **508** of the grid **502** may being identifiable from other elements **508** in the grid **502** by, for example, comprising a unique identifier. Such a unique identifier may be, for example, a portion of a random or pseudo random pattern, for example a portion of a speckle pattern produced by a laser. A pseudo random pattern may also be created, for example, by one or more LEDs whose emission is hindered by a mask comprising a pseudo random pattern of holes. Such a portion of a random or pseudo random pattern may be a group of high intensity areas, or spots, of a speckle pattern. Due to the random distribution of the spots, the configuration of adjacent spots in a particular group of spots is very likely unique to that group of spots, and hence a particular region of the speckle pattern, or the grid element **508** to which the particular region corresponds, can be uniquely identified amongst other regions or grid elements **508**.

FIG. **2***b* illustrates schematically an image acquired by the sensor **106***a* in the situation shown in FIG. **2***a*. The sensor **106***a* images the structured light pattern **502** that falls onto the object **504** and background **506** from a perspective slightly offset from the light source sensor **106***b*. In FIG. **2***b*, the structured light pattern **502** is represented by grid **502** comprising grid elements **508**, each of which are uniquely identifiable from other elements **508** of the grid **502**. For example, each grid element **508** may contain a region of speckle pattern (not shown) that can be uniquely identified as described above. The unique identifiers are represented in FIG. **2***b* as grid numbers **1**, **2**, **3** . . . **12**. Because sensor **106***a* is offset from light emitting sensor **106***b*, the image of the grid pattern from sensor **106***a* of grid pattern **502** falling on an object **504** closer to the sensor component **106** will appear offset from the grid pattern **502** falling on background **506** further away from the sensor component **106**. This can be seen in FIG. **2***b* as grid elements **5-8** are offset from grid elements **1-4** and **9-12** in both the x and y direction. If the position of grid elements imaged by sensor **106***a* is predetermined at a given background distance, then from the offset of elements relative to the predetermined positions, by using trigonometry, the distance of an object at the offset elements relative to the given background distance can be calculated. For example, from the offset of elements **5-8** relative to a reference image of the same grid at a predetermined distance, it can be determined from the image of FIG. **2***b* that there is an object (i.e. object **504** of FIG. **2***a*) at an x-y position corresponding to the coordinates of elements **5-8**, and that the object is a distance z from the sensor component **106**.

In such a way, depth information, i.e. the three dimensional coordinates of an object **504**, for example a user **200** or a portion of a user **200**, relative to sensor component **106** may be determined.

An alternative exemplary method by which user interface apparatus **100** may determining depth information is illustrated in FIG. **3**. Similarly to FIG. **2***a*, FIG. **3** illustrates a plan view (z–y plane) of an exemplary sensor component **106** sensing the three dimensional position of an object **504** and a background **506**. In this case, sensor component **106** comprises a single sensor **106***c* comprising a light source substantially co-located with a light detector. In this method, the length of time taken for a beam of light emitted from the light source to bounce off an object and return to the detector is recorded for different positions in the x-y plane (i.e. a "time-of-flight" measurement). In such a measurement, a given time for a round trip infers a given distance of the object from the sensor component **106**. For example, in FIG. **3**, the sum of the time for light paths **602** and **604** to and from the background **506** and the sum of the time for light paths **606** and **608** to and from the object **504** can be used to infer the distance of the background **506** at a given x-y position and the object **504** at a given x-y position respectively. In such a way, the three dimensional coordinates of an object **504**, for example a user or a portion of a user, relative to sensor component **106** may be determined.

It will be appreciated that any suitable method or means of determining the three dimensional coordinates of an object may be used, and the above described methods are examples only.

In some embodiments, from the determined 3D coordinates, the user interface apparatus **100** maps out the determined three dimensional coordinates of the environment sensed by sensor component **106** in a virtual three dimensional space **702**, as illustrated in FIG. **4***a*. In this exemplary embodiment, a user **200** is positioned relative to the sensor component **106** such that the three dimensional coordinates of the entire user **200** visible from the sensor component's **106** perspective is mapped out in a virtual three dimensional space **702** by the user interface apparatus **100**. It should be noted that, although not shown in FIG. **4***a*, according to the above described methods of determining depth information (i.e. the z coordinate) there will be a shadow of information behind the user from the point of view of the sensor component **106** in the virtual three dimensional space. This may be rectified, for example, by a second sensor component **106** at right angles to the sensor component **106**, although this is not typically necessary to accurately determine the 3D position of a portion of a user **200**.

From an analysis of the mapped out 3D coordinates of the user **200** in virtual space **702**, the user interface apparatus **100** may generate a virtual representation **704** of a user **200** in virtual 3D space **702**, as illustrated in FIG. **4***b*. The virtual representation **704** comprises joints (e.g. hip joint **706**) and extensions (for example forearm **708**) corresponding to those of the user **200**. The virtual representation **704** generated by the user interface apparatus **100** is that representation determined to have a high likelihood of matching the dimensions, positions and configurations of the respective joints and extensions of the actual user **200**. This may be achieved, for example, using three dimensional constrained fitting methods to fit a potential virtual representation **704** to the mapped out three dimensional coordinates of the user **200**. In some embodiments, a number of potential virtual representations **704** may be determined as candidates for being the most likely represent the actual user **200**. These candidate representations **704** may each be compared to a database of virtual representations of users predetermined to be faithful representations of actual users. This set of predetermined faithful representations may comprise those of a vast array of users of different dimensions in a vast array of different positions and configurations, thus substantially mapping out the landscape of representations likely to be adopted by a user **200**. The candidate representation **704** that most closely matches the largest number of predetermined faithful representations may be chosen as the representation **704** most likely to faithfully represent the actual user **200**. Such a comparison may be achieved, for example, by using decision tree methodologies, for example, "Random forest" machine learning methodologies. Similarly, the configuration of a part of a user's body, for example whether a hand of the user is in an open configuration, or in a closed, first like configuration, may be determined by comparison of the mapped out 3D coordinates of a hand portion of a user with an array of predetermined hand configurations. In this way, the hand configuration most likely to faithfully represent that of the user may be determined. This may utilise, similarly to as above, for example, "Random forest" machine learning methodologies. As an example, the Kinect™ for Windows™ Software Development Kit (SDK) **1.7** supports recognition of changes in hand configuration, for example so called "grip and release" recognition.

Determining the most likely faithful virtual representation **704** of the user **200** enables the user interface apparatus **100** to determine the dimensions, positions, and/or configurations of a user **200** or any portion or collection of portions of the user **200**. The above mentioned process may be repeated, for example, 30 times a second, to allow the user interface apparatus to track the position of a user or a portion of a user **200** in near-real time. For example, the user interface apparatus **100** may therefore track the three dimensional position of one or more points of a user's body such as a point on the user's hand, the centre of a user's head and/or an eye position, and configurations such as the configuration of a user's hand, in near real time. As described in more detail below, this allows a user to interact with selectable objects displayed on display screen **108**, just by the user moving portions of his or her body in free space.

FIG. **5***a* shows a schematic representation illustrating a user interface apparatus **100** according to an exemplary embodiment in use by an exemplary user **200**.

The user interface apparatus **100** according to the embodiment shown in FIG. **5***a* comprises a display screen **108**, and a sensing component **106**.

The user **200** comprises a hand **200***a*, an eye **200***c*, and a head **200***b*. The user is positioned so that the user is facing the display screen **108**, and the hand **200***a* is outstretched from the user's body in the direction of the display screen **108**.

The sensing component **106** comprises three sensors **106***a* **106***b* and **106***c* for tracking the position of the user's hand and the position of the user's head **200***b* and/or eye **200***c*, and for determining the configuration of the user's hand **100***a*, for example, whether the hand **100***a* is in an open configuration or a closed configuration.

The display screen **108** displays selectable objects **108***a* and **108***b* that are selectable by the user **200**.

The user **200** interacts with the user interface apparatus **100** using hand **200***a*. Using the hand **200***a*, the user **200** obscures from his or her own view the position **202** on the display screen **108** with which he or she wishes to interact.

In FIG. **5***a*, the user **200** has hand **200***a* positioned such that the region **202** of the display screen **108** is obscured from the user's **200** view.

The user interface apparatus **100** obtains information relating to a first tracked position, the first tracked position being a position of a first hand (i.e. hand **200***a*) of the user. The user interface apparatus **100** also obtains information relating to a second tracked position, the second tracked position being a position of the head **200***b* or an eye **200***c* of the user **200**.

A position of the user's hand **200***a* (i.e. a "first tracked position") and the position of an eye **200***c* of the user (an example of a "second tracked position") may define two points of a straight line **204**, also referred to herein as the eye-hand line **204**.

A position of an eye **200***c* of the user **200** may refer to a position between the eyes of the user (e.g. the midpoint between the eyes of the user), or the position of the centre on an eye, or pupil of an eye of the user. For example, the position of the centre of a user's hand **200***a*, and the centre of a user's eye **200***c* may be used to define the eye-hand line **204**. The eye **200***c* may be, for example, the dominant eye of the user, i.e. the eye of the user from which visual input is stronger or preferred. The dominant eye **200***c* may be, for example, identified to the user interface apparatus by suitable input by the user.

From obtaining information relating to the first tracked position (e.g. the tracked position of the user's hand **200***a*) and the second tracked position (e.g. the tracked position of a user's eye **200***c*) as described above, the user interface apparatus may calculate the eye-hand line **204** in its virtual three dimensional space **702**.

In FIG. **5***a*, the eye-hand line **204** intersects with the display screen **108** at point **206**, which point **206** is contained within the region **202** of the display screen **108** that is obscured from the user's **200** view by the user's hand **200***a*. If the position and dimensions of the display screen **108** are determined by the user interface apparatus **100**, for example by a calibration process described below, then the user interface apparatus **100** may represent the display screen in the same virtual three dimensional space **702** in which the virtual representation of the user **704** is represented, and hence where the eye-hand line **204** is virtually represented. In this case, the user interface apparatus **100** may determine the point on the display screen in virtual space **702** at which the virtual eye-hand line intersects the display screen in virtual space **702**. In such a way, the user interface apparatus **100** may infer the position on the actual display screen **108** with which the user **200** wishes to interact.

Alternative positions other than the position of an eye **200***c* of the user **200** may be used to define the second tracked position, but which would still result in the eye-hand line **204** intersecting with the display screen **108** in a region **202** of the display screen **108** obscured from the view of the user **200**. For example, the midway point between the two eyes **200***c* of the user **200** may be used. This may be advantageous as this would allow a point of intersection **206** of the head-hand line **204** with the display screen **108** contained in the region **202** obscured from the user's vision to be determined without requiring a knowledge of which eye **200***c* of the user **200** is stronger or preferred or otherwise should be used in defining the head hand line **204**.

The second tracked position may alternatively be a position of the head **200***b* of the user, for example the centre of a user's head **200***b*.

A position of the user's hand **200***a* (i.e. "first tracked position") and the position of the head **200***b* of the user **200** (an example of a "second tracked position") may define two points of a straight line **204**, referred to in this case as the head-hand line **204**. Although the term "eye-hand line" is used in the various discussions below, in some embodiments a head-hand line is used instead.

The eyes of the user **200** are typically located approximately halfway down the vertical length of the user's head **200***b*, and are set at a substantial depth into the user's head. In this case, the use of the position of the centre of a user's head **200***b* in defining the second tracked position may still result in the head-hand line **204** intersecting with the display screen **108** in a region **202** of the display screen **108** obscured from the view of the user **200**. In this case, the head-hand line **204** may be used by user interface apparatus **100** in place of eye-hand line **204** when determining the portion of the display screen with which the user wishes to interact.

Using a position of a user's head as a second tracked position may be advantageous in situations where it is difficult to detect the position of the eyes or an eye of the user, or in situations where it is more efficient to track the centre of a user's head **200***b* compared to tracking the position of an eye **200***c* or eyes of the user **200**.

The hand **200***a* may be either hand of the user **200**, and may for example be that hand of the user determined to be closest to the display screen **108**, or alternatively or additionally that hand of the user which is the more raised of the two hands of the user **200**.

By tracking a position of the user's hand **200***a* (i.e. a first tracked position) and a position of the user's head **200***b* or eye **200***c*) (i.e. a second tracked position) in three dimensional space with one or more of the sensors **106***a*, **106***b* and **106***c*, the user interface apparatus **100** can determine the eye-hand line **204** (or head-hand line **204** as appropriate), and hence determine a point of intersection **206** of the line **204** with the display screen **108** contained within the region of the display screen **202** obscured from the user's view by the user's hand **200***a*. In such a way, the user interface apparatus **100** can determine a position on the display screen **108** with which the user **200** is to interact.

It should be noted that if the second tracked position is the position of a user's head **200***b*, for example the position of the centre of the user's head **200***b*, rather than an eye position, due to the physical separation of the user's eyes from the centre of a user's head, there may be a discrepancy between the point of intersection **206** of the head-hand line **204** determined by the user interface apparatus **100**, and the centre of the region **202** obscured from the user's vision (i.e. the region that the user intends to select). FIG. **5***b* illustrates schematically a potential offset D between point of intersection **206***a* of a head-hand line **204***a* (defined using the centre **200***e* of the user's head **200***b*), and the point of intersection **206***b* of an eye-hand line **204***b* (defined using a position of the user's eye **200***c*) according to an example. In this example, both points of intersection **206***a* and **206***b* are contained within the region **202** obscured from the user's vision. However, the point of intersection **206***b* (determined using the user's eye position) is closer to the centre of the region **202** obscured from the user's vision than the point of intersection **206***a* (determined using the user's head position). The point of intersection determined using the head-hand line **204***b* therefore less consistently results in correct selection of the object intended for selection.

Therefore, using an eye position (e.g. the position of the user's eye **200***c*) as the second tracked position as opposed to a head position (e.g. the centre **200***e* of a user's head **200***b*) allows the user interface apparatus **100** to more accurately and consistently determine the position on the display screen **108** with which the user **200** wishes to interact, and hence may reduce, for example, occurrences of erroneous user-interface interaction. This enables a more intuitive interaction with the user interface.

The user interface apparatus **100** may store information relating to the current position of selectable objects on display screen **108**. The user interface apparatus **100** may determine that selectable object **108***b* displayed on the display screen **108** contains eye-hand line **204** intersection point **206**, meaning that selectable object **108***b* is at least partially obscured from the user's view, and therefore determine that selectable object **108***b* may be an object to be selected. Conversely, selectable object **108***a* does not contain intersection point **206**, and therefore is not determined to be an object to be selected or otherwise of present interest to the user **200**.

As described in more detail below, the user may select the object **108***b* at least partially obscured from the user's view **200** by changing a configuration of the user's hand **200***a*. If the user interface apparatus **100** determines that such a change in configuration of a user's hand **200***a* occurs whilst selectable object **108***b* contains intersection point **206**, the selectable object **108***b* is determined as selected. Further operations can be performed on a selected selectable object as described in more detail below.

Such determinations as described above may be made, for example, using processor **104** (not shown in FIG. **5***a* or **5***b*) and memory **106** (not shown in FIG. **5***a* or **5***b*) of the user interface apparatus **100**.

With a user interface apparatus **100** as described above, a user **200** may interact with a displayed object (e.g. selectable objects **108***a*, **108***b*) in a way he or she **200** may naturally interact with objects, i.e. typically when selecting (i.e. picking up) an object, a user at least partially covers that object with his or her hand, and hence at least partially obscures that object from his or her view. Further, such an interaction avoids requiring a user to move a pointer displayed on the display screen toward a target because the position of the hand and the position of objects displayed on the screen can be directly and visually inferred from his or her own perspective. Such an intuitive interface therefore obviates the need for a pointer to be displayed, and reduces fatigue in the user compared to interfaces using pointers whereby the user must first move the arm in order to find the pointer, move the pointer toward a target, and then adjust speed and amplitude of movement in order precisely to reach the target.

FIG. **6***a* shows the display screen **108** of the user interface apparatus **100** from the point of view of the user **200** (not shown in FIG. **6**). On the display screen **108** there are displayed **6** selectable objects **106***a* to **108***f*. The positions of the selectable objects **106***a* to **106***f* on the display screen are determined by the user interface apparatus **100**, for example because the image displayed on the display screen **108** is derived from information generated by the processor **104** of the user interface apparatus **100**. In this example, the user **200** wishes to select selectable object **108***b*. The user therefore positions his or her hand **200***a* so as to obscure object **108***b* from his or her view. In FIG. **6***a*, the user's hand is spread out in a substantially open configuration. Note that, as can be seen more clearly in FIG. **5**, the user's hand **200***a* need not necessarily touch the screen **108** or be any specific distance from display screen **108**, the hand **200***a* need only obscure at least a portion of the object **108***b* from the user's **200** view. The centre of the user's hand **200***a* is represented by dot **300**. In this example, the eye-hand line **204** (not shown in FIG. **6***a*) contains the centre of the user's hand. The position **206** on the display screen **108** at which the user's eye-hand line **204** (not shown in FIG. **6***a*) intersects the display screen **108** is therefore, from the user's perspective, aligned with the centre of the user's hand **300**. The user interface apparatus **100** may determine that selectable object **108***b* contains the intersection point **206**, and may, for example, determine object **108***b* as a candidate object for selection by the user **200**. In some embodiments, the user interface apparatus **100** may determine object **108***b* as a selected object based solely on a determination that selectable object **108***b* contains the intersection point **206**.

In some exemplary embodiments, if the user interface apparatus **100** determines that an object **108***b* is a candidate object for selection by the user **200**, then the user interface apparatus **100** may cause the object **108***b* to be displayed differently.

FIG. **6***b* illustrates an exemplary change to selectable object **108***b*, where selectable object **108***b* is increased in size with respect to its size before it was determined as a candidate object for selection. Other changes may be made to an object determined a candidate object for selection, such as, for example, a change of colour, a change of representation of the object, for example the shape of the object, or a complete change in the image symbolising the object. Similarly, the background **302** of the display screen **108** may change, for example change colour or intensity, when such a determination is made. Additionally or alternatively, a sound may be generated by a sound generating means such as a speaker on determination of an object possible for selection, which sound may be, for example, correlated to the object itself. For example, if the object was a representation of a panda, on determination of the object as a candidate object for selection, the representation of the panda may change (for example the face of the panda may change from a neutral expression to a smiling expression), the size of the representation may change, and/or a sound of a panda may be generated. These changes may advantageously alert the user to the possibility of selecting the object **108***b* which is at least partially obscured from the view of the user **200** by the user's hand **200***a*.

In other embodiments, no such changes occur on determination that the object is a candidate object for selection. In yet further embodiments, no such determination that an object is a candidate object for selection is made by user interface apparatus **100**.

FIG. **6***c* is an illustration showing a user selecting selectable object **108***b*, and is the same as FIG. **6***a*, except that the user has performed a grab-like action, in doing so has changed the configuration of the hand **200***a* from an outstretched open configuration to a fist-like closed configuration. Note that the object **108***b* still remains at least partially obscured from the user's view.

In one embodiment, the user interface apparatus **100** determines when the configuration of the hand has changed from an open configuration as in the hand **200***a* of FIG. **3***b* to a closed configuration as in the hand **200***a* of FIG. **3***c*. In response to such a determination, the user interface apparatus **100** determines the point of intersection **206** of the eye-hand line **204** with the display screen **108**. In response to a determination that the intersection point **206** is located within a selectable object **108***b* displayed on the display screen **108**, then the selectable object **108***b* is determined as selected by the user. In the example of FIG. **6***c*, since the intersection point **206** does lie within the selectable object **108***b* as the hand **200***a* changes to a closed configuration, then the object **108***b* is determined as selected.

The user interface apparatus **100** need not necessarily determine that a hand configuration of the user has changed in order to determine that a selectable object **108***b* is selected. In some embodiments, the user interface apparatus **100** continuously (or near continuously, e.g. 30 times a second) determines the point of intersection **206** of the eye-hand line **204** with display screen **108**. In this case, in response to a determination that the intersection point **206** is located within a selectable object **108***b* displayed on the display screen **108**, then the selectable object **108***b* is determined as selected by the user. In such a way, a selectable object **108***b* may be selected by a user **200** without a need for the user **200** to change a configuration of his or her hand **200***a*. This may be advantageous, for example, in situations where it is difficult to determine the configuration of a user's hand. In other embodiments, the selectable object may be selected on the basis of the intersection point **206** being located within a selectable object **108***b* displayed on the display screen **108** for a predetermined duration of time, for example the object may only be determined as selected after the intersection point **206** has been located within the selectable object for 1 second.

In some embodiments, a selectable object **108***b* determined as selected may be moved from one location on the display screen **108** to another by the user **200**. FIG. **6***d* is an illustration of a display screen as viewed from the user's perspective, and is the same as FIG. **6***c*, except the user has moved his or her hand **200***a*, whilst still in the closed, fist-like configuration, to a different location in his or her field of view, and the position of the selected object **108***b* on the display screen **108** has moved accordingly. The original position of object **108***b* before moving is represented by dashed box **108***b**. The position to which the object **108***b* is moved depends on the position to which the user has moved his or her hand **200***a*, and accordingly the position on the display screen **108** to which the point of intersection **206** of the eye-hand line **204** (not shown in FIG. **6***d*) has moved. As a result, as can be seen in the example of FIG. **6***d*, whilst the object **108***b* is selected, even if it is being moved, the object **108***b* still contains the point of intersection **206**, and the user's hand **200***a* still at least partly obscures the object **108***b* from the user's view. In some embodiments, if the user moves his or her hand **200***a* such that the point of intersection **206** moves outside of the display screen **108**, the object **108***b* may be moved outside of the display screen accordingly. In other embodiments, in such a case, the object **108***b* may be constrained to not leave the display screen **108**, and may for example, in such a case, be automatically deselected. In another example, in such a case, the object may remain in a given position, for example the last position where the point of intersection **206** was determined to be within the display screen **108**, until it is determined that the user moves his or her hand **200***a* such that the point of intersection **206** returns to within the display screen **108**, at which time the object will return to the point of intersection **206** as so newly determined.

In some embodiments, in order to deselect an object **108***b* selected as described above, the user changes the configuration of his or her hand **200***a* from a closed configuration (as in FIG. **6***c* or **6***d*), back to an open configuration (as in FIG. **6***a*). FIG. **6***e* shows an illustration of display screen **108** from a user's perspective, and is the same as FIG. **6***d*, except the hand **200***a* has changed from a closed configuration to an open configuration. On determination that the user's hand **200***a* has changed from a closed configuration to an open configuration, the user interface apparatus **100** determines that the selected object **108***b* is unselected. In the example shown in FIG. **6***e*, the object **108***b* remains at the same position on the display screen **108** at which it was determined to be unselected. In this case, and movement of the user's hand **200***a* whilst in the open configuration will have no effect on the deselected object **108***b*, as it is now deselected. This is illustrated in FIG. **6***f*, which is an illustration of the display screen **108** from the user's **200** perspective, and is the same as FIG. **6***e*, except that the user has moved his or her hand **200***a*, still in the open configuration, to a different position, but the object **108***b* (now deselected) remains in the same position on the display screen **108**.

In the case where the user interface apparatus selects a selectable object **108***b* solely on the basis that the point of intersection **206** of the eye-hand line **204** with display screen **108** is located within the selectable object **108***b*, or has been so located for a predetermined amount of time, then the user need not maintain his or her hand configuration in a closed configuration (or indeed any particular configuration) in order to move the selected object. In such a case, the object may be deselected automatically, for example, when the user causes the point of intersection **206** to be outside of the display screen. In another example, the object may be deselected if the user ceases movement of the selected object for a predetermined duration of time, for example if the user interface apparatus **100** determines that, whilst an object is selected, the point of intersection **206** has not moved by more than a predetermined amount (e.g. distance or degree) in the last 1 second, the user interface apparatus **100** may determine that the selected object is deselected.

It will be appreciated that an object **108***b* may also be selected or deselected on the basis of a determined change in the configuration of the hand **200***a* of the user **200** other than a change between an open configuration and a closed configuration or vice versa. Any other suitable configuration change which can be reliably detected by the user interface apparatus **100** may be used. For example, a suitable change in configuration may be a change in the way in which the palm of an outstretched hand **200***a* is facing, for example a change from a configuration where the palm of the hand **200***a* is facing towards the display screen **108** to a configuration where the palm of the hand **200***a* is facing away from the display screen.

Another such suitable change in configuration may be a "pinching" action, whereby a user's hand changes from an open configuration with the fingers outstretched to a closed configuration whereby one or more fingers and the thumb of the hand are brought together whilst still being extended radially from the hand. Another such suitable change in configuration may be on the occurrence of one or more "tapping" actions, whereby the user's hand changes from an open configuration where the fingers are outstretched, for example in a first plane, for example a plane substantially parallel with the plane of the display screen **108**, to a second configuration where the hand has rotated about the wrist such that the fingers are outstretched, for example, in a second plane rotated with respect to the first plane, for example a plane substantially perpendicular to the plane of the display screen. In some embodiments, a change in configuration may only be recognised after two or more of these "tapping" actions, such that, for example, a user selects an item by "double tapping" on an object.

In some exemplary embodiments, further operations may be performed on a selected selectable object **108***b* other than moving the location of the object. For example, a user **200** may remove or delete a selected virtual object **108***b* (or data associated therewith) in a similar way as the user **200** may remove a physical object which he or she is holding: by throwing it away. Such a naturalistic interface has, for example, advantages in the ease with which a user may engage effectively with it. Such a "throwing away" action typically comprises a sudden change in position or velocity of the object coupled with the user releasing (deselecting) the object.

In order to achieve this virtually, the user interface apparatus **100** may determine the rate at which a user **200** changes the position of his or her hand **200***a* in a given direction when a given selectable object **108***b* is selected. This can be determined directly by tracking the change in the determined hand **200***a* position in three dimensional coordinates, or by tracking the change in point of intersection **206** of the eye-hand line **204** with the display screen **108**. Alternatively the user interface **100** may determine this for example by determining the displacement or distance travelled by the selected object **108***b* on the display screen **108** in a given time (i.e. the average velocity or average displacement velocity of the object **108***b* over a given time interval). The user interface apparatus **100** may additionally or alternatively determine such an average velocity of the object **108***b* over a number of such time intervals, and in such a way determine an acceleration of the object **108***b*. When the user interface apparatus **100** determines that a selected selectable object **108***b* is unselected (for example as described above with reference to FIG. **6***e*) the velocity of the object **108***b* and/or the acceleration of the object **108***b* in one or more time period(s) immediately preceding the determination that the selectable object **108***b* is unselected is determined. The user interface apparatus **100** may compare this determined velocity of the object **108***b* and/or determined acceleration of the object **108***b* to a predetermined threshold of velocity and/or predetermined threshold of acceleration respectively. In the case where the determined velocity and/or acceleration of the object **108***b* is above the respective threshold, then the user interface apparatus **100** may perform a further processing action on the object; and if not then not perform a further processing action. An exemplary further processing action may be a deletion of the object **108***b*. This deletion may correspond to removing the object **108***b* from display on the display screen **108**, and/or moving data associated with the object **108***b* from one directory of the memory (e.g. memory **106** or **112**) in which the data is stored to another, and/or removing the data altogether.

FIG. **7**, similarly to FIG. **5**, illustrates a user **200** using a user interface apparatus **100** according to another exemplary embodiment. In this embodiment, the user interface apparatus comprises a gaze-sensor **110** for use in sensing the gaze direction **404** of the user **200**, comprising glasses **402** worn by the user **200**. The glasses **402** may track the rotation of the eye **200***c* of the user relative to the glasses **402**, for example by tracking the position of the pupil of the eye using infra-red cameras. Since, in operation, the glasses **402** are fixed relative to the user's head **200***b*, the glasses **403** can track the rotation of the eye **200***c* relative to the user's head **200***b*. Since the position of and direction in which the user's head is facing relative to the display screen **108** may be determined by the user interface apparatus **100**, then it may determine the gaze direction **404** of the user **200** relative to the display screen **108**. Alternatively, the gaze sensor **110** may comprise other components (not shown) for determining the gaze direction **404** of the user **200** relative to the display screen **108**. These components may comprise, for example, magnetometers to track the change in orientation of the head of the user **200***b* with respect to a given direction.

Alternatively, gaze sensor **110** may comprise any other suitable technology for determining the gaze direction of the user relative to the display screen **108**.

In this embodiment, the user interface apparatus **100** may determine a point **406** on the display screen at which the user is looking by extrapolating determined gaze direction **404** from the determined tracked position of the user's eye **200***c* in three dimensional space.

It should be noted that, in FIG. **7**, although the user is looking at point **406** on the display screen **108**, region **202** of the display screen **180** is still obscured from the user's view by the user's hand **200***a*. In this case, the user interface apparatus **100** still determines the point of intersection **206** of the eye-hand line **204** with the display screen **108** as a point for use in controlling selectable objects **108***a* or **108***b* displayed on the display screen **108**.

In FIG. 7, the point of intersection **206** of the eye-hand line **204** with the display screen **108** is such that it is contained within selectable object **108***b*. However, the point **406** on the display screen **108** at which the user **200** is looking is separated from the point of intersection **206** of the eye-hand line **204** with the display screen **108** by a distance d (not shown in FIG. **7**).

In one example, the object **108***b* is selected by the user. If it is determined that the object **108***b* is unselected by the user (for example if the user interface apparatus determined that the configuration of the user's hand **200***a* changes from a closed configuration to an open configuration) then the user interface apparatus **100** determines the distance d between the point **406** and the point **206**. If it is determined that the distance d is above a predetermined threshold, the user interface apparatus may perform a further processing operation on the object **108***b*, and if it is determined to be below the predetermined threshold then it may not perform a further processing operation. The further processing operation may be, for example, a deletion of the object as described above, or may be any other conceivable further processing operation, for example: save, copy, zoom, rotate, resize etc.

In another example, the user interface apparatus may determine that the point of intersection **206** of the eye-hand line **204** and the point **406** on the display screen **108** at which the user is looking are held separated a distance d from each other by more than a threshold amount, for more than a threshold amount of time. For example, a user **200** may hold his or her hand **200***a* in one position whilst his or her gaze is held directed at a different position on the display screen **108**, for example, for more than 1 second. Upon such a determination, the user interface apparatus **100** may determine that a further processing action should be performed, for example, to re-arrange all of the selectable objects **108***a*, **108***b* etc. on the display screen **108** into a pattern on the display screen **108**, for example in a grid distribution. In such a way the user may control the user interface apparatus **100** to position the selectable objects **108***a*, **108***b*, etc. such that, for example, they may be more easily and readily distinguished and selected by the user **200**.

In such ways as described in the examples above, the user interface apparatus **100** can obtain more degrees of control from the user **200**, and as such provide a more efficient interface with which the user **200** may interact. In some embodiments, the user interface apparatus **100** may determine that the user **200** has a low competence level in using the user interface apparatus **100**, e.g. that the user **200** is a beginner, and may not be used to the control paradigm provided by user interface apparatus **100**. For example, the user interface apparatus may determine that the user **200** has changed the configuration of his or her hand **200***a* from an open configuration to a closed configuration (i.e. signifying to select an object) at a position on the display screen at which there is no selectable object **108***b* to select. The user interface apparatus **100** may determine that such an occurrence has happened successively more than a predetermined number of times. In this case, the user interface apparatus **100** may cause a pointer, or some symbolic indicator to be displayed on the display screen at a position related to the determined point of intersection **206** in order that the user may be reminded of the location on the display screen with which he or she is interacting. The pointer may only be displayed for a predetermined period of time, for example 5 seconds to allow the user to orientate themselves with the display screen. Alternatively, the pointer may only be displayed for a predetermined number of determined changes in hand configuration of the user, or otherwise until such time as the user **200** successfully selects an object **108***b*. The pointer may be arranged such that it is not obscured from the view of the user **200** by the user's hand **200***a* when it is displayed on the display screen. Such an exemplary pointer is shown in FIG. **8**, which shows display screen **108** displaying selectable objects **108***a* to **108***f*, and also displaying circular pointer **802** centred on the determined point of intersection **206**, and with a large enough diameter so as to not be completely obscured from the user's view by the user's hand **200***a*.

The user interface apparatus **100** may additionally or alternatively determine a low competence level, if an action is repeated by a user more than a predetermined number of times. For example, if a user selects an object, moves it, and then replaces the object to at or nearby its original position, say, more than three times successively, this may be indicative of a user selecting an object other than the object he or she intends to select, and the user interface apparatus **100** may determine a low competence level and display a pointer as described above accordingly to remind the user of the control paradigm. It will be appreciated that the above are examples only, and that repetition of any user action more than any pre-defined or dynamically determined number of times may cause a low competence level to be determined, and hence a pointer or other control paradigm reminder, such as for example a message, to be displayed.

In some embodiments, the dimensions and position of the screen **108** in virtual three dimensional space **702** is determined by the user interface apparatus in a calibration procedure.

In some embodiments, the point of intersection of two determined eye-hand lines **204** associated with a user **200** standing in two different positions is used by user interface apparatus **100** to infer a three dimensional coordinate of the display screen **108**.

FIG. **9** shows an illustration of a portion of such a calibration process, where a user **200** stands in two different locations **901** and **902**, and in each location positions his or her hand **200***a* into a position so as to obscure from his or her view, a predetermined location **904** on the display screen **108**.

For example, in such a calibration process, the user interface apparatus **100** may cause to be displayed on display screen **108** instructions instructing the user to position his or her hand **200***a* so as to obscure a given symbol **904** indicated on the display screen, for example located at a corner of the display screen **108**, and once in place to perform a "grab-action" i.e. change his or her hand **200***a* from an open configuration to a closed configuration. Upon determining such an action has occurred, the user interface apparatus **100** may record the eye-hand line **910** in virtual space **702**. The user interface apparatus **100** may then cause to be displayed instructions for the user to repeat this process (not shown in FIG. **9** for clarity), whilst the user **200** remains in the same location (for example at location **901**), for different symbols on the display screen **108**, for example positioned at different corners **908**, **912** of the display screen **108**. The user interface apparatus **100** may then cause to be displayed instructions for the user to repeat this process, but from a different location, for example location **902**, and in such a way determine the dimensions and position in virtual space **702** of the display screen **108**, as described in more detail below.

In FIG. **9**, the respective resulting two eye-hand lines **910** and **920** (produced when user **200** obscures region **904** from his or her view and performs a grab-action when standing at locations **901** and **902** respectively), have a point of intersection, or near intersection at point **906**.

For each location **901** and **902**, the user interface apparatus **100**, using sensor component **106**, determines a representation **704** of the user in three dimensional virtual space **702**, and from this determines the eye-hand line (**910** or **920**) in virtual three dimensional space **702**, as described above. Eye-hand line **910** for example may be described in virtual space **702** by an equation in virtual space **702**: If E is the eye coordinate and H is the hand coordinate, then the coordinates of any point on the eye-hand line $L_{(E,H)}$ is given by

$$L_{(E,H)}: P(t)=E=t(H-E)=E+tu \quad (1)$$

where t is the equation parameter and u=E−H is the direction vector of $L_{(E,H)}$.

In this case, if the user positions his or her hand **200***a* to obscure a given region **904** on the screen from two different locations **901** and **902**, then the user interface apparatus **100** may determine the corresponding system of eye-hand line equations:

$$L_1: P(t_1)=E_1+t_1u$$

$$L_2: P(t_2)=E_2+t_2v \quad (2)$$

Where v is the corresponding direction vector of L_2, and where the subscript "1" refers to the user location **901** and the subscript "2" refers to the user location **902**. If the two lines L_1 and L_2 intersect, they define a unique point P (i.e. intersection point **906**) at which they intersect. Such an intersection point can then be used to define the three dimensional coordinates of the region of the display screen **108** in virtual space **702** corresponding to region **904** on display screen **108**. In some exemplary calibrations, instead of the user only obscuring one region **904** of the display screen **108** with his or her hand **200***a*, at each location **901** and **902**, the user sequentially obscures two or more regions of the display screen, for example two corners of the display screen **108**. In this case, two or more coordinates of the display screen **108** can be determined in virtual space **702**. In the example where it is predetermined at the user interface apparatus **100** that the display screen is rectangular, if the calibration process is performed with the regions as three of the four corners of the display screen **108** from two different locations **901** and **902**, then the exact dimensions and position of the display screen in virtual space **702** can be determined. This is because if it is predetermined that the screen is rectangular, then the position of the fourth corner of the display screen **108** can be inferred from the positions of the other three corners. If the shape of the display screen **108** is not predetermined, then more regions of the display screen may be included in the calibration process until an appropriate mapping of the position of the display screen to three dimensional virtual space **702** coordinates is achieved.

In some scenarios, as illustrated in FIG. **10**, two eye-hand lines L_1 and L_2 may not actually intersect, and may only near-intersect. In this case, the intersection point **906** may be determined as the midway of the shortest line connecting L_1 and L_2. For example, considering the system of equations (2), let $w=P_1(t_1)-P_2(t_2)$ be a vector between point $P_1(t_1)$ on line L_1 and point $P_2(t_2)$ on line L_2. If the two lines are not parallel, then they are closest at unique points $P_1(t_{1c})$ and $P_2(t_{2c})$: either they intersect and $P_1(t_{1c})=P_2(t_{2c})$, or they only near intersect, and the segment $[P/(t_{1c}), P_2(t_{2c})]$ is the unique segment perpendicular to both lines L_1 and L_2. In the case of near intersection, the vector $w_c=P_2(t_{2c})-P_1(t_{1c})$ is the unique vector perpendicular to both line direction vectors v and u, that is the vector w_c satisfies the system of equations (3):

$$u \cdot w_c=0$$

$$v \cdot w_c=0. \quad (3)$$

Expressing w_c in terms of u, v, E_1 and E_2, i.e. $w_c=E_1+t_{1c}u-(E_2+t_{2c}v)$, the system (3) becomes:

$$u\cdot(E_1-E_2)+t_{1c}u\cdot u-t_{2c}u\cdot v=0$$

$$v\cdot(E_1-E_2)+t_{1c}v\cdot u-t_{2c}v\cdot v=0. \quad (4)$$

System (4) can be manipulated to produce equations for the parameters t_{1c} and t_{2c} that define the points $P_1(t_{1c})$ and $P_2(t_{2c})$ respectively,

$$t_{1c}=\frac{v\cdot(E_1-E_2)\times u\cdot v-u\cdot(E_1-E_2)\cdot v^2}{u^2\cdot v^2-(v\cdot u)^2} \quad (5)$$

$$t_{2c}=\frac{u\cdot(E_1-E_2)\times u\cdot v-v\cdot(E_1-E_2)\cdot u^2}{(u\cdot v)^2-v^2\cdot u^2}$$

The parameters t_{1c} and t_{2c} define the points $P_1(t_{1c})$ and $P_2(t_{2c})$ respectively, which can then be used to define the segment $[P_1(t_{1c}), P_2(t_{2c})]$. The centre of the segment $[P_1(t_{1c}), P_2(t_{2c})]$ can then be used to define the point of near intersection, and hence the position in virtual space **702** of the associated region of the display screen **108**.

In such a way, even if the eye-hand lines **910** and **920** of the calibration process only nearly intersect, the position of the region **904** in virtual space **702** can be determined by the user interface apparatus **100**.

In some embodiments, the user interface apparatus may determine that the length of the segment $[P_1(t_{1c}), P_2(t_{2c})]$ is above a certain threshold, and hence that the inferred point of near intersection in virtual space is likely to be a poor representation of the corresponding region **904** of the display screen **108**. In such cases, the calibration process may be repeated until the length of all segments corresponding to respective near intersection of the calibration process is less than a certain threshold.

In some embodiments, after a first eye-hand line **910** has been recorded for a given region **904** by the user interface apparatus in a step of the calibration process, then when the user **200** is positioning his or her hand to define eye-hand line **920** in a later stage of the calibration process, the display screen displays a dynamic measurement of the shortest distance between lines **910** and **920**, so that the user may position his or her hand so as to minimise this measurement, and hence produce a more accurate calibration. Instead of displaying the shortest distance, an indication of whether the shortest distance is within an acceptable range, for example, less than 5 cm, is displayed. This could be represented as a traffic light type system, where is the shortest distance is unacceptable, say >10 cm, the screen displays red, if the shortest distance is acceptable, say <10 cm but >5 cm it displays orange, and is the shortest distance good, say <5 cm, then it displays green.

In some embodiments, the user interface apparatus **100** only records an eye-hand line (e.g. **901**, **902**) in a calibration process if it is stable enough to provide an suitably accurate determination of screen position, for example only if the corresponding eye and hand positions are stable to within 2 cm for a 10 second period.

It should be noted that once the position of the display screen **108** in virtual space **702** is determined by the user interface apparatus **100**, as long as the display screen **108** and sensor component **106** are not moved relative to each other, the user interface apparatus **100** can accurately determine the intersection point **206** with which a user **200** wishes to interact, for any such user, independent of the user's dimensions, body type, etc.

In an exemplary calibration process, the calibration steps described above with reference to region FIGS. **9** and **10** are repeated, for example, for corners **904**, **908**, and **912** of display screen **108**, such that the user interface apparatus **100** determines the three dimensional coordinates (A, B, C) of corners **912**, **908**, and **904** respectively in virtual space **701**. In use, the user interface apparatus **100** may determine a eye-hand line **204** defined in three dimensional virtual space **702** by eye-hand line $L_{(E,H)}$ of equation 1 containing points P(t). In this case, the user interface apparatus **100** may determine the position on the display screen **108** at which the user wishes to interact by calculating the point of intersection P of eye-hand line $L_{(E,H)}$ and the plane (A, B, C) in virtual space **702**.

In some embodiments, the 2D coordinates of the point P within the 2D display screen may be calculated, for example for use as an input to an application requiring the 2D coordinates of the point of user interaction on a display screen **108**.

In order to express P as such a two dimensional display screen coordinate, the user interface apparatus **100** may calculate the coordinate transformation needed to define A as the origin, AB/|AB| as the x vector, and BC/|BC| as the y vector of the virtual space **702**. Such a coordinate transformation may comprise a translation and three rotations as described below. First, the user interface apparatus **100** may define one of the coordinates of the corners, for example A, as an origin O of the virtual space **702**. In order to obtain A as the origin of virtual space **702**, the translation required from A to the origin O of the virtual space **702** is calculated. Three rotations to compensate for the three possible rotations about this origin the plane (A, B, C) may then be calculated. In a first rotation, an edge of the screen, for example the bottom edge of the screen defined by AB is projected onto the plane (O, x, z) in coordinate system of the virtual space **702**, where O is the origin, x is the x axis vector and z is the z axis vector in virtual space **702**. The angle α between x and the projection of AB on (O, x, z) may then be calculated using:

$$AB\cdot x=|AB|\cdot|x|\cdot\cos\alpha\Leftrightarrow\alpha=\arccos\left(\frac{|AB\cdot x|}{|AB|\cdot|x|}\right).\tag{6}$$

From equation 6, the rotation—α around the z axis needed to be applied to the plane (A, B, C) to effect the coordinate transformation i.e. to correctly align AB with the x axis of the virtual space coordinate system, can be inferred. The same procedure is then applied for the other axes x and y to infer the corresponding rotations required about those axes accordingly.

The above calculated transformations may then be applied to three dimensional intersection coordinate P in order to transform it to a two dimensional coordinate P' within the display screen.

As described above, once the calibration process has been performed, as long as the relative positions of the display screen **108** and sensor **106** do not change, the same coordinate transformations can be used for different users, independent of user dimensions, body type, etc. and so the calibration need not be repeated.

It will be appreciated that although the above calibration process is described with reference to eye-hand lines, in situations where a head position is being used as the second tracked position, head-hand lines may be used by user interface apparatus **100** in the calibration process instead.

In some embodiments, the user interface apparatus may detect and track multiple users at the same time.

In some embodiments, the user interface apparatus **100** may track the positions of multiple user's and correspondingly determine and carry out interactions with the display screen **108** for each individual user.

In some embodiments, for example where it is desirable that only one user at a time is able to interact with display screen **108**, user interface apparatus **100** may determine an "active user", and only obtain and/or use tracking information relating to that user. An active user may be determined for example as the user that is located the shortest distance from the display screen **108**, for example based on the determined hip joint location of the virtual representation **704** of each user in virtual space **702**.

FIG. **11** shows a schematic flow diagram of steps in a method performed by a user interface apparatus **100** to allow a user to select selectable objects **108***b* displayed on a display screen **108** according to an embodiment.

Step S**1101** comprises tracking a hand **200***a* position, the hand position being a position of a first hand **200***a* of a user, tracking a head **200***b* or an eye **100***c* position of the user, and detecting hand configuration of the first hand **200***a*.

Step S**1102** comprises determining one or more object **108***b* positions of the one or more selectable objects **108***b* on the display screen **108**.

Step S**1103** comprises determining when the detected hand configuration of the first hand **200***a* of the user **200** has changed to a first predetermined configuration, for example to a closed, first like configuration. If the detected hand configuration has changed to a first predetermined configuration, then the method proceeds to step S**1104**, and if it hasn't then the method returns to step S**1101**.

Step S**1104** comprises determining, responsive to a determination that the detected hand configuration has changed to the first predetermined configuration, and based on the tracked hand **200***a* position, the tracked head **200***b* or eye **200***c* position and the determined one or more object **108***b* positions, whether a said selectable object **108***b* is located at a first screen position, the first screen position being a position on the display screen **108** such that the first hand **200***a* at least partly obscures the user's view of the selectable object **108***b*. If it is determined that the selectable object is located at the first screen position, then the method progresses to step S**1105**, and if it is not, the method returns to step S**1101**. In some embodiments, alternatively, if it is determined that there is no selectable object located at the first screen position, then the user interface apparatus may determine a low competence level of the user, and may for example display a pointer as described above.

Step S**1105** comprises, (in the case of a determination that the first hand does at least partly obscure the user's view of the selectable object) determining that the selectable object is selected.

Such a method as described above may be for example, written into code executable by a user interface apparatus **100**, or any other suitable processing system, which code may be stored on a computer readable medium, and which when executed by the user interface apparatus **100** or suitable processing system, causes the user interface apparatus **100** or suitable processing system to perform the method as described above.

The above embodiments are to be understood as illustrative examples of the invention. It is to be understood that any feature described in relation to any one embodiment may be used alone, or in combination with other features described, and may also be used in combination with one or more features of any other of the embodiments, or any combination of any other of the embodiments. Furthermore, equivalents and modifications not described above may also be employed without departing from the scope of the invention, which is defined in the accompanying claims.

The invention claimed is:

1. A method performed by at least one computer processor, for use in a user interface apparatus for selecting a selectable object on a display screen, the display screen being arranged to display one or more selectable objects, the method comprising:

obtaining first information regarding a first tracked position, the first tracked position being a position of a center of a first hand of a user;

obtaining second information regarding a second tracked position, the second tracked position being a position between the eyes of the user;

determining one or more object positions of the one or more selectable objects on the display screen;

determining a first screen position based on a point of the display screen intersected by a straight line passing through both the first tracked position and the second tracked position, the first screen position being a position on the display screen such that the first hand at least partly obscures the user's view of the selectable object;

in response to a determination that a hand configuration of the first hand has changed to a closed hand configuration, determining, based on the first screen position and the one or more object positions, whether the selectable object is located at the first screen position;

in the case of a determination that the selectable object is located at the first screen position, determining that the selectable object is selected;

in response to a determination that the first tracked position has changed while the hand configuration is maintained in the closed hand configuration, controlling the selected selectable object to move on the display screen;

in response to a determination that the configuration of the first hand has changed from the closed hand configuration to an open hand configuration, determining that the selected selectable object is deselected obtaining information regarding a tracked gaze, the tracked gaze direction being a direction in which the user is looking;

responsive to a determination that the hand configuration has changed to the open hand configuration, determining a second screen position based on the tracked gaze direction information, the second screen position being a position on the display screen at which the user is looking; and

responsive to a determination that the second screen position differs by more than a threshold degree from the object position of the selected object, performing a deletion process to delete the selected selectable object.

2. The method according to claim **1**, wherein the second tracked position is a position of the centre of the head of the user.

3. The method according to claim **1**, the method comprising:

in response to the determination that the hand configuration has changed to the open hand configuration, controlling the selected selectable object to cease the movement.

4. The method according to claim **1**, the method comprising:

if it is determined that a rate of change of the determined first tracked position is above a given threshold, performing the deletion process to delete the selected selectable object in response to the determination that the hand configuration has changed to the open hand configuration.

5. The method according to claim **1**, wherein the first tracked position and the second tracked position are both tracked as three dimensional coordinates.

6. The method according to claim **5**, the method comprising a calibration process, the calibration process comprising:

obtaining third information regarding a third tracked position, the third tracked position being a position of a head or an eye of the user;

with the user's head or eye positioned in the third tracked position: sequentially determining a first plurality of hand positions such that the first hand at least partly obscures the user's view of a plurality of predefined positions on the display screen, thereby defining a first plurality of straight lines each containing the third tracked position, one of the first plurality of hand positions and a respective one of the predefined position on the display screen;

obtaining fourth information regarding a fourth tracked position, the fourth tracked position being a position of the head or the eye of the user, different to the third tracked position;

with the user's head or eye positioned in the fourth tracked position: sequentially determining a second plurality of hand positions such that the first hand at least partly obscures the user's view of each of the plurality of predefined positions on the display screen, thereby defining a second plurality of straight lines each containing the fourth tracked position, one of the second plurality of hand positions, and a respective one of the predefined positions on the display screen; and

for each of the plurality of predefined positions on the display screen, determining, for a given predefined position, a point of intersection or near intersection of a respective straight line of the first plurality of straight lines with a respective straight line of the second plurality of straight lines and containing the given predefined position.

7. The method according to claim **1**, the method comprising:

responsive to a determination that the detected hand configuration has changed to the closed hand configuration at a determined first screen position at which no said selectable object is located, causing to be displayed, on the display screen, at the determined first screen position, a pointer.

8. The method according to claim **1**, the method comprising;

responsive to a determination that an operation of the user interface has been repeated by the user more than a predetermined number of times, causing to be displayed a pointer on the display screen.

9. The method according to claim **1**, wherein the obtaining first information includes tracking the first tracked position with a sensor which is adjacent to the display screen and directed towards the user, and

the obtaining second information includes tracking the second tracked position with the sensor.

10. A non-transitory computer readable medium having instructions stored thereon a program, when executed by a processing system, cause the processing system to:

obtain first information regarding a first tracked position, the first tracked position being a position of a center of a first hand of a user;

obtain second information regarding a second tracked position, the second tracked position being a position between the eyes of the user;

determine one or more object positions of the one or more selectable objects on the display screen;

determine a first screen position based on a point of the display screen intersected by a straight line passing through both the first tracked position and the second tracked position, the first screen position being a position on the display screen such that the first hand at least partly obscures the user's view of the selectable object;

in response to a determination that a hand configuration of the first hand has changed to a closed hand configuration, determine, based on the first screen position and the one or more object positions, whether the selectable object is located at the first screen position;

in the case of a determination that the selectable object is located at the first screen position, determine that the selectable object is selected;

in response to a determination that the first tracked position has changed while the hand configuration is maintained in the closed hand configuration, control the selected selectable object to move on the display screen;

in response to a determination that the configuration of the first hand has changed the closed hand configuration to an open hand configuration, determine that the selected selectable object is deselected;

obtain information regarding a tracked gaze direction being a direction in which the user is looking;

responsive to a determination that the hand configuration has changed to the open hand configuration, determining a second screen position based on the tracked gaze direction information, the second screen position being a position on the display screen at which the user is looking; and

responsive to a determination that the second screen position differs by more than a threshold degree from the object position of the selected object, performing a deletion process to delete the selected selectable object.

11. A user interface apparatus for selecting a selectable object on a display screen, the display screen being arranged to display one or more selectable objects, the user interface apparatus comprising:

one or more processors configured to:

obtain first information regarding a first tracked position, the first tracked position being a position of a center of a first hand of user;

obtain second information regarding a second tracked position, the second tracked position being a position between the eyes of the user;

determine one or more object positions of the one or more selectable objects on the display screen;

determine a first screen position based on a point of the display screen intersected by a straight line passing through both the first tracked position and the second tracked position, the first screen position being a position on the display screen such that the first hand at least partly obscures the user's view of the selectable object;

in response to a determination that a hand configuration of the first hand has changed to a closed hand configuration, determine, based on the first screen position and the one or more object positions, whether the selectable object is located at the first screen position;

in the case of a determination that the selectable object is located at the first screen position, determine that the selectable object is selected;

in response to a determination that the first tracked position has changed while the hand configuration is maintained in the closed hand configuration, control the selected selectable object to move on the display screen;

in response to a determination that the configuration of the first hand has changed from the closed hand configuration to an open hand configuration, that the selected selectable object is deselected;

obtain information regarding a tracked gaze direction being a direction in which the user is looking;

responsive to a determination that the hand configuration has changed to the open hand configuration, determining a second screen position based on the tracked gaze direction information, the second screen position being a position on the display screen at which the user is looking; and

responsive to a determination that the second screen position differs by more than a threshold degree from the object position of the selected object, performing a deletion process to delete the selected selectable object.

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